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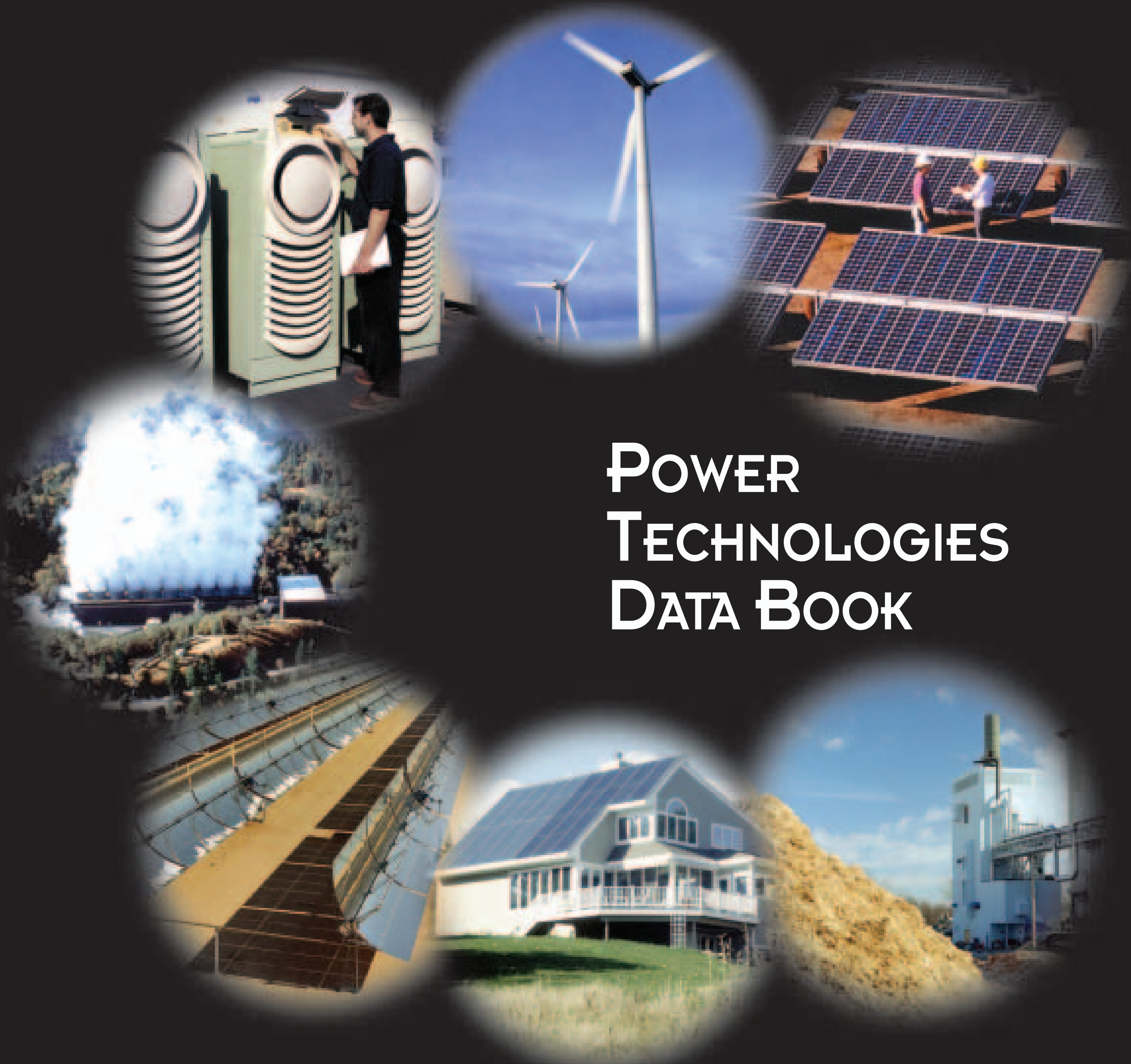

POWER TECHNOLOGIES DATA BOOK

PREPARED BY THE

NATIONAL RENEWABLE ENERGY LABORATORY

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Power Technologies Data Book

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Integrated Biomass R&D

Mission-Supporting Goals and Objectives

The EE Integrated Biomass R&D subprogram includes Biopower Systems and Biofuels Energy Systems in the Energy and Water Development Appropriations Bill and the Agriculture Vision of the Future, Black Liquor Gasification, and portions of the Forest Products Vision in Interior and Related Agencies Appropriations Bill. These programs collectively support the Biomass R&D Act of 2000 by providing baseload renewable electricity, transportation fuel options, and industrial products and chemicals that offer a choice for substantial environmental benefits and national energy security. These efforts result in technologies that work toward industrial biorefineries, which will make biomass energy and products competitive with conventional fossil-based options.

Integrated Biomass R&D, in partnership with industry, will assist in the development of an integrated biomass industry. This will be accomplished through the utilization of biopower technologies that are clean, reliable, and competitive with conventional power systems; and research, development, and validation of technologies that will reduce reliance on imported transportation fuels and chemical feedstocks. When successful, these technologies will promote rural economic development, reduce greenhouse gas emissions, and provide for productive utilization of agricultural residues and segregated municipal solid wastes.

The Integrated Biomass R&D subprogram is in the process of making a major transition to become more cohesive and focused on some areas, while de-emphasizing other elements that are either deemed a lower program priority or should be performed by some other agency with a strong interest in biomass – such as the Department of Agriculture (USDA) and DOE's Offices of Science and Fossil Energy. EE biomass vision and roadmap documents have been drafted, a Biomass Technical Advisory Committee has been in place more than a year, and an EE Coordination Office is working closely with its counterparts at USDA. A high-level EE Bio-Board also has been established and has taken a leadership role in reorienting the biomass programs previously administered along end-use sector lines under Transportation Technologies, Power Technologies, and Industrial Technologies. This FY 2003 budget request is the culmination of efforts from all of these committees with final decisions at the corporate EE level made by managing EE Bio-Board. As a result, R&D priorities and project funding have been grouped into the areas of feedstock production, gasification, fuels and chemicals, processing and conversion, and crosscutting technologies. While the FY 2003 budget request is presented along the existing budget categories, it will likely change in FY 2004 to better reflect a more integrated framework.

The Draft Biobased Products and Bioenergy Roadmap has been used by the EE Bio-Board to prioritize R&D activities for FY 2003. Feedstock research supported by DOE focuses on preconversion "in-field" processing of feedstocks to improve energy density and reduce costs of feedstocks at the plant gate. Other major areas identified as part of the roadmap that serve as the basis for the DOE leveraged program requested for FY 2003 include Processing and Conversion, and Product Uses and Distribution. Processing alternatives include both biochemical and thermochemical methods such as fermentation and gasification. Multiple value-added products are viewed as enabling the overall increase in product use for the major energy applications – fuels and electricity. In addition, major changes in R&D include the curtailing of research to support agronomic feedstock development at DOE, eliminating support for the Regional Biomass Energy Program (RBEP), and the elimination of R&D related to cofiring.

Program Strategic Performance Goals

ER2-1: Biopower
Biopower R&D activities will increase the testing, verification, and demonstration of the component systems of cost-effective and efficient biomass gasification combined-cycle systems from 0 percent in 2000 to 75 percent in 2006.

ER2-2: Biofuels
Biofuels R&D activities will reduce the production cost of cellulose-based ethanol to $1.20 per gallon by 2005, and to $1.07 per gallon in by 2010.

Performance Indicator
Biomass - Percentage of component systems tested, verified, and demonstrated
Biofuels - The cost per gallon of ethanol from cellulosic matter is the indicator of performance for the biofuels activity.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Initiated a feasibility study and conceptual design of gasifier-based cofiring processes. Conducted competitive solicitation and selected at least one partner for innovative biofuels production technologies and made awards to qualified research organizations. Conducted competitive solicitation and selected at least one partner for demonstrating the conversion of cellulosic feedstock at a corn ethanol plant. (Met goal).	Initiate testing of Small Modular BioPower Systems, which have both domestic and international applications. Develop a prototype yeast capable of fermenting multiple biomass-derived sugars for ethanol production.	Establish three R&D platforms for gasification-system testing and integration, to support the program's gasification strategic plan and the Program Strategic Performance Goal (PSPG). Evaluate an improved enzyme preparation developed by a leading enzyme manufacturer for reducing the cost of producing ethanol from biomass and update the program's reference computer model of the production process.

In the past 10 years, total primary bioenergy use has increased from 2.6 Quads in 1990 to 3.2 Quads in 2000, but the use has shifted from heat-only to more high-value uses – electricity, fuels and combined heat and power (CHP). Biomass primary energy use for power, fuels, and products could grow between 40 percent and 100 percent by 2010 depending on the successful R&D coupled with aggressive policy measures.

Biopower Program-supporting goals to help reach this projected potential include demonstrating high-efficiency biomass gasification, combined-cycle systems and technologies for low-emission biorefinery options. Biofuels-supporting goals include the technology for the production of low-cost sugars, the development of optimized fermentation organisms, and the development of strong partnerships with industry leaders.

Integrated Biomass R&D

Objectives that support the Biopower Program mission and goals include the successful testing and verification of components and systems required for cost-effective and efficient biomass gasification, combined-cycle systems including gasifiers, gas cleanup/conditioning, power-generation technologies (gas turbines, fuel cells, etc.), and integration and control technologies.

By 2003, three R&D platforms will be established for gasification-system testing and integration at the appropriate scale of development that support the Biopower Program's gasification strategic plan.

Objectives that support the Biofuels Program mission and goals outlined below rely on the strengthening of existing – and development of new – industrial R&D partnerships, as well as policies that enable the demonstration technologies to be conducted with reduced financial and market risk.

Biofuels

By 2004, at least one ethanol facility will be in operation using biomass wastes, and a partnership with the corn-ethanol industry will complete testing of ethanol production from corn fiber.

By 2005, the cost of cellulase enzymes for conversion of cellulosic feedstocks will be reduced tenfold relative to year 1999 baseline, to a cost of 5 to 10 cents per gallon of ethanol produced.

By 2010, technologies will be developed that can produce ethanol at a cost of $1.07 per gallon at the ethanol plant gate, excluding distribution, retail markup, and incentives. Year 2000 baseline for cellulosic ethanol is $1.40 per gallon.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Biopower Energy Systems					
Thermochemical Conversion	3,400	5,904	6,000	96	1.6%
Systems Development	25,284	29,024	23,625	-5,399	-18.6%
Feedstock Production	3,300	1,000	1,000	0	0.0%
Regional Biomass Energy Program	1,335	778	0	-778	-100.0%
Crosscutting Biomass R&D	6,000	2,500	2,375	-125	-5.0%
Subtotal, Biomass Power Systems	39,319	39,206	33,000	-6,206	-15.8%
Biofuels Energy Systems					
Bioconversion Platform	12,114	23,887	20,805	-3,082	-12.9%
Ethanol Production	21,026	19,932	27,325	+7,393	37.1%
Crosscutting Biomass R&D	6,350	2,500	2,375	-125	-5.0%
Renewable Diesel Alternatives	750	750	1,500	750	100.0%
Feedstock Production	3,600	1,000	1,000	0	0.0%
Regional Biomass Energy Program	2,212	777	0	-777	-100.0%
Subtotal, Biofuels Systems	46,052	48,846	53,005	4,159	8.5%
Total, Biomass R&D	85,371a	88,052	86,005	-2,047	-2.3%

FY 2001 has been reduced by $897,000 to reflect SBIR/STTR Transfer

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Geothermal Technology Development

Mission-Supporting Goals and Objectives

The Geothermal Technology Development Program directly supports the organizational mission to develop clean, competitive, reliable power technologies for the 21st century. To this end, the program works in partnership with U.S. industry to establish geothermal energy as an economically competitive contributor to the U.S. energy supply, capable of meeting a significant portion of the nation's heat and power needs. Current program goals include doubling the number of states with geothermal electric power facilities to eight by 2006; reducing the levelized cost of generating geothermal power to 3-5 cents/kWh by 2010; and supplying the electrical power or heat energy needs of 7 million homes and businesses in the United States by 2015. The goal of doubling the number of states with geothermal power facilities, and thereby broadening the base of geothermal development in the United States, is a Departmental Program Strategic Performance Goal (PSPG).

The program's approach to achieving its goals is to expand the use of known geothermal fields through near-term technology development; identify new cost-effective resources through integrated exploration techniques and tools; reduce both risk and cost through improved drilling technologies and surface systems; and broaden the resource base through development of Enhanced Geothermal Systems.

Research activities are implemented through directed work at the national laboratories, competitive solicitations to universities and industry, and cost-shared public-private partnerships.

Capital costs associated with developing a typical geothermal well field range from $300 to $600 per kilowatt installed. These costs represent 30 percent to 50 percent of the total cost of the facility. The program is pursuing two strategies to reducing the absolute costs of the well field. One involves reducing the number of wells needed to produce a unit of energy through improved identification, understanding, and characterization of the geothermal resource. The other addresses reducing well costs through advanced technology.

Advances in exploration technology have the potential to significantly increase the availability of geothermal resources. Only one in five geothermal exploration wells succeeds in locating economically viable resources. The program has an objective of improving the success rate in exploratory drilling from 20 percent in 2000 to 40 percent by 2010.

At the same time, the economics of drilling individual wells can be improved by innovative drilling technology. To this end, the program has the objective that by 2004, the rate of penetration will increase by 25 percent over drilling rates in 2000. This will contribute to the overall objective of reducing well costs from $300 per foot in 2000 to $150 per foot in 2008.

Finally, advanced materials and innovative technologies can improve the economics of future plant systems. The program is working to decrease the capital costs of surface systems by 20 percent relative to year 2000 technology by the year 2010.

As a baseload power generation technology with very high reliability, geothermal energy contributes to the nation's energy security, especially in stabilizing the electricity grid in remote areas. Geothermal energy production emits negligible amounts of greenhouse gases, making the technology a viable alternative in addressing global climate change. As such, the program is responsive to these issues and many of the recommendations contained in the National Energy Policy (NEP) report.

Program Strategic Performance Goal

ER2-3: Geothermal Energy Geothermal Energy R&D activities will result in twice as many states with geothermal electric power facilities by 2006.

Performance Indicator: The number of states with geothermal electric power facilities.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Selected industrial partners to build two cost-shared geothermal power plants using Enhanced Geothermal System (EGS) technology.	Complete construction of a small-scale (300 kW to 1 MW) geothermal power plant for field verification. An FY 2000 NREL study revealed considerable opportunity for small-scale geothermal in several Western states.	Begin operation of a small-scale geothermal power plant in the state of New Mexico, thereby increasing the diversity of the nation's energy supply and the geographical distribution of geothermal electric power generation.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Geoscience and Supporting Technologies	7,300	6,916	7,700	784	+11.3%
Exploration and Drilling Research	8,200	8,084	12,100	+4,016	+49.6%
Energy Systems Research and Testing	11,123	12,299	6,700	-5,599	-45.5%
Total, Geothermal Technology Development	26,623a	27,299	26,500	-799	-2.9%

FY 2001 has been reduced by $288,000 to reflect SBIR/STTR Transfer.

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Hydrogen Research

Mission-Supporting Goals and Objectives
The Hydrogen Program includes research and validation projects for the development of safe, cost-effective hydrogen energy technologies that support and foster the transition to a hydrogen economy. To enable a future that includes hydrogen energy, four strategies are pursued that will provide benefits in efficiency, environment, and economy. **Hydrogen Research** The use of hydrogen will be expanded in the near-term by working with industry, including hydrogen producers, to improve efficiency, lower emissions, and lower the cost of technologies that produce hydrogen from natural gas. Distributed refueling stations will be installed collaboratively with industry, which will demonstrate a hydrogen production cost of $12 - $15 per million Btu for pressurized hydrogen from natural gas by 2015. DOE will work with fuel cell manufacturers to develop hydrogen-based electricity storage and generation systems that will enhance the introduction and penetration of distributed, renewables-based utility systems. By 2010, a reversible hydrogen fuel cell system will be validated. By 2015, carbon emissions will be reduced by 1.3 MMTCE for less than $600 per kW and 13.7 MMTCE by 2020. A portion of the hydrogen program also will support the FreedomCAR initiative and will be coordinated with the Department of Transportation and EE's Transportation programs to demonstrate safe and cost-effective fueling systems for hydrogen vehicles in urban nonattainment areas and to provide on-board hydrogen storage systems. By 2010, a safe, low-cost hydrogen storage system will be developed and validated for use onboard a vehicle to achieve a 350-mile range. Finally, the department will work with the national laboratories to lower the cost of technologies that produce hydrogen directly from sunlight and water. An integrated process development unit will be operational by 2020 that will continuously produce hydrogen from water and biomass. Hydrogen, the most plentiful element in the universe, is the ideal fuel. Hydrogen can be oxidized in a fuel cell, combusted in a conventional engine, or simply burned. Its only byproduct is water. Hydrogen can be produced from fossil, nuclear, or renewable resources and as a transportable fuel; it has greater flexibility than electricity for a transportation vehicle and remote-area use. Many scientists see it as the basis for the total sustainable clean energy economy of the future.
Program Strategic Performance Goal
ER2-4: Hydrogen Hydrogen R&D activities will demonstrate a conversion technology that will improve the cost of hydrogen production from natural gas from $3.75 per kilogram in 2000, when produced in large quantities, to $2.50 per kilogram in 2006. **Performance indicator:** Cost of hydrogen ($/kg) produced in large quantities.

Hydrogen Research

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Produced 20 cubic meters per hour of hydrogen via steam reforming of biomass pyrolysis oil in a process development unit.	Construct process development unit of ceramic membrane system for membrane system tests for hydrogen production.	Complete the design, development, and testing of the 10,000 psi hydrogen storage tank.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Core Research and Development	14,438	14,426	19,331	4,905	34.0%
Technology Validation	9,009	10,320	15,000	4,680	45.3%
Analysis and Outreach	3,147	4,437	5,550	1,113	25.1%
Total, Hydrogen Research and Development	26,594a	29,183	39,881	10,698	36.7%

FY 2001 funding shown has been reduced by $287,000 for SBIR/STTR transfers.

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Hydropower

Mission-Supporting Goals and Objectives

Working with industry and other federal agencies, the Hydropower Program's R&D activities support the development of a new generation of more environmentally friendly hydropower turbines. The FY 2003 request will permit the Hydropower Program to facilitate the development of a commercially viable turbine technology capable of reducing the rate of fish mortality to 2 percent or lower by 2010 (compared with turbine-passage mortalities of 5 to10 percent for the best existing turbines and 30 percent or greater for some turbines), while maintaining downstream dissolved oxygen levels of at least 6 mg/L to ensure compliance with water quality standards. Developing more environmentally friendly turbine technology also will help reverse the decline in hydroelectric generation, an important alternative to fossil fuel generation.

Efforts to develop and test innovative environmentally friendly turbines designed specifically for low head/low power and micro-hydro applications could provide hydropower for many sites, such as canal drops, where dams would not be necessary.

The pilot-scale proof-of-concept testing of the Alden advanced turbine design will verify predicted biological and hydraulic performance and provide the basis for full-scale prototype testing. The FY 2003 request will provide for the accelerated testing of a full-scale prototype of this turbine at an operational hydropower site.

Biological testing of additional turbine designs provided by industry will provide additional options for new projects or upgrades to existing projects. These activities, together with supporting biological research, will provide industry with technology capable of reducing turbine-induced fish mortality to 2 percent or less by 2010.

Testing of low-head/low-power turbine designs provided by industry, together with the resource and technology assessment activities, will provide industry with environmentally friendly designs and data on the resource base for this underutilized source.

Program Strategic Performance Goal

ER2-5: Hydropower
Hydropower R&D activities will ensure commercialization of a fish passage technology capable of reducing turbine-induced fish mortality to 2 percent or less by 2010 in new fish-friendly turbines.

Performance indicator: Percentage fish mortality of turbines in the current stage of the testing and development process.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Test facility completed for pilot-scale testing of the innovative turbine design developed by the Alden Research Laboratory team.	Pilot-scale biological and hydraulic testing initiated.	Completion of pilot-scale testing, providing the basis for future full-scale testing at an operational site. Successful testing will provide industry with a proven design, helping attain the 2% mortality goal.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Advanced Turbine Research and Development	4,936	5,018	7,489	2,471	49.2%
Total, Hydropower	4,936a	5,018	7,489	2,471	49.2%

FY 2001 has been reduced by $53,000 to reflect SBIR/STTR transfer.

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Solar Energy

Mission-Supporting Goals and Objectives

The United States has the best solar resource of any industrialized nation in the world. Solar energy is clean, abundant, distributed, safe, and secure. The Office of Solar Energy Technologies leads the federal research to develop next-generation technologies to harness this domestic energy resource, thereby providing a cleaner and more sustainable environment, guarding against fuel price volatility, and greatly enhancing both national energy and homeland security – all important goals of the National Energy Policy. The solar program supports R&D on a tremendous range of applications including on-site electricity generation, thermal energy for space heating and hot water, and large-scale power production.

Photovoltaics (PV) - Research is focused on increasing domestic capacity by lowering the cost of delivered electricity and improving the efficiency of modules and systems. Fundamental research at universities will be increased to develop nonconventional, breakthrough technologies. Laboratory and university researchers will work with industry on large-volume, low-cost manufacturing, such as increasing deposition rates to grow thin-film layers faster, improving materials utilization to reduce cost, and improving in-line monitoring to increase yield and performance. Specific goals by 2006 are to:

1. Reduce the direct manufacturing cost of PV modules by 30 percent from the current average cost of $2.50/Watt to $1.75/Watt;
2. Identify and begin prototype development of two new leapfrog technologies that have the potential for dramatic cost reduction;
3. Establish greater than 20-year lifetime for PV systems by improving the reliability of balance-of-system components and reducing recurring costs by 40 percent; and
4. Work with the U.S. PV industry to facilitate achievement of their roadmap goals of 1 gigawatt cumulative U.S. sales (export and domestic) by 2006, and 30 gigawatts by 2020.

Solar Buildings - Emphasis will be placed on development of the “Zero Energy Building” concept and reducing the cost of solar water heating by using lightweight polymer materials that can replace the heavy copper and glass materials used in today’s collectors. Specific goals are to:

1. Integrate solar technology and energy-efficient buildings resulting in an annual energy bill of less than $600 for an average-size home by 2004, and “net-zero” by 2010;
2. Complete R&D on new polymers and manufacturing processes to reduce the cost of solar water heating from today’s 8 cents/kWh to 4 cents/kWh by 2004.

Concentrating Solar Power (CSP) - CSP systems currently offer the least expensive source of solar electricity (12-14 cents/kWh) with systems ranging in size from several kW distributed systems to multi-MW power plants. Several years ago, the department asked the National Research Council to conduct a review of its renewable energy programs. The council findings cast doubt over the potential of large-scale solar plants, like troughs and towers, to achieve the technology advances required to penetrate broad domestic energy markets. Based on this report, the department is focusing its solar R&D on priority distributed and building applications.

Solar Energy

Program Strategic Performance Goal

ER2-7: Solar Technologies Solar Technologies R&D will reduce the price paid for a photovoltaic system by the end user (including operation and maintenance costs) from a median value of $6.25 per Watt in 2000 to $4.50 per Watt in 2006 (equivalent to reducing from $0.25 to $0.18 per kilowatt hour).

Performance Indicator: Dollar per Watt paid by the end user, trendable from $9 per Watt in 2000.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Developed a 14 percent efficient stable prototype thin-film photovoltaic module.	Reduce manufacturing cost of PV modules to $2.25 per Watt (equivalent to $0.20 to $0.30 per kWh price of electricity from an installed solar system).	Reduce manufacturing cost of PV modules to $2.10 per Watt (equivalent to $0.19 to $0.28 per kWh price of electricity from an installed solar system).

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Concentrating Solar Power					
Distributed Power System Development	6,275	5,224	1,932	-3,292	-63.0%
Dispatchable Power System Development	3,613	3,716	0	-3,716	-100.0%
Advanced Component Research	3,677	3,386	0	-3,386	-100.0%
Southwest Resource Opportunity	0	489	0	-489	-100.0%
Navajo Electrification Project	0	367	0	-367	-100.0%
Subtotal, Concentrating Solar Power	13,565	13,182	1,932	-11,250	-85.3%
Photovoltaic Energy Systems					
Fundamental Research	17,560	21,700	30,400	8,700	40.1%
Advanced Materials and Devices	37,000	26,900	29,793	2,893	10.8%
Technology Development	19,700	17,555	13,500	-4,055	-23.1%
Southwest Resource Opportunity	0	3,083	0	-3,083	-100.0%
Navajo Electrification Project	0	2,313	0	-2,313	-100.0%
Subtotal, Photovoltaic Energy Systems	74,260	71,551	73,693	2,142	3.0%
Solar Building Technology Research					
Solar Water and Space Heating	3,069	3,000	4,000	1,000	33.3%
Zero Energy Buildings	800	1,404	8,000	6,596	469.8%
Southwest Resource Opportunity	0	174	0	-174	-100.0%
Navajo Electrification Project	0	131	0	-131	-100.0%
Subtotal, Solar Building Technology Research	3,869	4,709	12,000	7,291	154.8%
Total, Solar Energy	91,694a	89,442	87,625	-1,817	-2.0%

FY 2001 has been reduced by $987,000 to reflect SBIR/STTR Transfer.

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Wind Energy Systems

Mission-Supporting Goals and Objectives

The Wind Energy Systems Program has a strong history of success in delivering results for the R&D investment, with the cost of electricity generation from wind reduced by a factor of 20+ during the past 20 years – this while becoming the fastest growing energy supply source in the United States and worldwide. A key element of this success is attributable to effective cost-shared public-private partnerships with industry and a wide range of stakeholder organizations. The current generation of wind turbines, however, is limited to areas with high (Class 5 and 6) wind speeds to be economic, which sharply restricts their use. The development of wind turbines that can operate cost competitively in areas with moderate (Class 3 and 4) wind speeds will increase the wind resource that can be tapped by a factor of 20, and greatly broaden the areas of application. Low wind-speed technology development is recognized in the National Energy Policy (NEP) as an opportunity for expanding wind energy use, supported by FY 2002 Congressional language, and is a Departmental Program Strategic Performance Goal (PSPG).

For large wind-energy systems with rated turbine capacity of more than 100 kilowatts, the program's R&D activities focus on supporting U.S. industry efforts to reduce life-cycle cost of energy to levels that will allow wind to compete in bulk electric-power markets. The program also conducts R&D focusing on smaller wind energy systems for serving a broad range of distributed energy needs. Singular cost performance targets are not appropriate for distributed wind systems, which instead require an approach based on relative improvement within scale, application, and market segments. Current program goals include:

- Reduce cost of energy from large wind systems to 3 cents per kilowatt hour:
    - in Class 6 wind resources by 2004 (2002 baseline - 4 cents);
    - in Class 4 wind resources by 2010 (2002 baseline - 5.5 cents), PSPG ER 3-6.
- Reduce cost of energy from distributed wind systems to achieve same cost effectiveness in Class 3 wind resources by 2007, against Class 5 baseline costs in 2002 ranging from 10 to 15 cents per kilowatt-hour.

The program leads research, testing, and field verification through laboratory and public-private partnerships to achieve these goals, which responds to the NEP recommendation to develop next-generation technologies. The program also conducts activities with a broad range of stakeholders to overcome barriers to wind energy use. Based on independently peer-reviewed national energy modeling projections, achievement of the program's large wind systems cost goals would increase U.S. installed wind energy capacity by 11,000 megawatts in 2010, and by 45,000 megawatts in 2020, relative to projections of capacity growth without federal investment in low wind speed technology. These projections assume no significant change from 2002 in policy relating to U.S. wind power development.

Program Strategic Performance Goals

ER2-6: Wind Energy
Wind Energy R&D activities will provide the technologies to reduce the cost of wind-powered electricity generation in Class 4 wind areas (13 mph annual average) from 5.5 cents per kilowatt-hour in 2002 to 3 cents per kilowatt-hour by 2010.

Wind Energy Systems

Performance Indicator: Cost of wind-powered electricity generation. Projection of 3 cents per kilowatt-hour in Class 4 winds (13 mph annual average) by 2010 compared with 5.5 cents in 2002.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Advanced wind hybrid control system technology developed jointly with USDA Agricultural Research Center will be commercially available	Initiate development of an improved resolution national wind resource atlas, focusing first on new maps for high-priority regions for commercial projects	Complete low wind-speed turbine conceptual design studies, and fabricate and begin testing advanced wind-turbine components optimized for low wind-speed application initiated under industry partnership projects.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Applied Research	14,579	13,950	10,800	-3,150	-22.6%
Turbine Research	12,428	10,498	18,900	+8,402	80.0%
Cooperative Research and Testing	12,125	14,150	14,300	150	1.0%
Total, Wind Energy Systems	39,132a	38,598	44,000	+5,402	14.0%

FY 2001 has been reduced by $421,000 to reflect SBIR Transfer.

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High Temperature Superconductivity R&D

Mission-Supporting Goals and Objectives

The High Temperature Superconductivity (HTS) program works in partnership with industry to conduct the precommercial R&D required for U.S. companies to commercialize HTS electric power applications. The program has two mission-supporting goals: 1) develop an alternative to conventional electric wire with 100 times the capacity and no resistance; and 2) develop advanced electrical equipment using these wires, which is typically half the size of conventional alternatives and has only half the energy losses. The HTS program goals focus on development of the next generation of superconducting wire, which will be fundamental to all electrical systems; and on the HTS electrical system technology to utilize superconductivity to increase capacity, reliability, and efficiency.

In response to the National Energy Policy recommendation to expand research and development on transmission reliability and superconductivity, the HTS program objectives focus on electrical grid needs, for example, developing precommercial superconducting power cables by 2006 that relieve urban bottlenecks, and developing superconducting high-capacity transformers that improve electricity distribution by 2007. Several aggressive, industry-led public-private partnership projects are designing, building, and testing advanced technologies such as generators, transformers, motors, transmission cables, and flywheel energy systems in the Superconductivity Partnership Initiative subprogram. The industry-led Second Generation Wire Development subprogram exploits breakthroughs at DOE national laboratories that promise unprecedented current-carrying capacity in HTS wires. Industry teams are working with national laboratory scientists to scale-up the discoveries to commercial processes. The Strategic Research subprogram, led by the national laboratories, provides the underlying knowledge base needed to accomplish superconducting systems.

Program Strategic Performance Goals

ER2-8: High-Temperature Superconductivity
High-Temperature Superconductivity (HTS) R&D activities will develop HTS wire capable of carrying 100 times the power of comparable copper wire – with zero electrical resistance by 2007.

Performance Indicator: Wire power carrying capacity.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Documented 6,000 hours (100% load) operation of the first successful high-temperature superconducting power delivery system to power an industrial use. Installed first of a kind superconducting electrical transmission cables to replace existing delivery to an urban substation serving 14,000 customers in Detroit, Michigan and began testing operation and reliability.	Complete initial testing of Detroit superconducting transmission cable and document operational costs and reliability.	Increase the capability to reproducibly fabricate 10- meter length of Second Generation HTS wire to carry 50 amps of electricity and 1-meter lengths that carry 100 amps from a 40 amp base.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Superconductivity Partnership Initiative	14,000	12,000	17,838	5,838	48.7%
Second Generation Wire Development	12,000	11,000	20,000	9,000	81.8%
Strategic Research	10,426	9,388	10,000	612	6.5%
Total, High Temperature Superconducting R&D	36,426a	32,388	47,838	15,450	47.7%

FY 2001 has been reduced to reflect SBIR/STTR transfer.

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Distributed Energy Resources

Mission-Supporting Goals and Objectives

DOE's Distributed Energy Systems activities are implemented within the EE Office of Distributed Energy Resources (DER) and support efforts to achieve the department's distributed energy goal of at least 20 percent of new installed capacity by 2020 (nonrenewable < 50 MW).

Strategies address technology development, standards-making, infrastructure, energy delivery, technical, institutional, and regulatory needs. The strategy is accomplished through three subprogram activities: Energy Storage Research, Transmission Reliability, and DER Electric System Integration (formerly Distributed Power). These three subprograms focus on improving the reliability of electric power generation and distribution system through the integration and interconnection of distributed energy resources. Transmission Reliability research develops and integrates real-time measurement and control networks, and electric-system models and tools for high-voltage transmission systems. This research ensures reliable and efficient grid operations and markets while integrating distributed energy in the competitive marketplace. Energy Storage Research seeks to develop advanced energy storage systems with an energy density greater than 5kWh per square foot at a cost below $700/kWh. The subprogram funds the design of integrated systems, research on advanced storage system components, and development of economic and performance models. DER Electric System Integration addresses technical, regulatory, and institutional barriers; and develops interconnection standards for deployment of DER near the potential users. Performance targets include: a certification process for certifying compliance of interconnection equipment with the national interconnection standard by 2003; prototype interconnection technology that reduces the installed cost of interconnection systems for small distributed generation and storage (300 kW or less) by 30 percent from today's $150/kW to $100/kW by 2005; next-generation intelligent autonomous plug-and-play interface and control by 2010. These activities support Chapter 7 NEP recommendations to develop a comprehensive energy-delivery system. The department partners with the Electric Power Research Institute (EPRI), the National Rural Electric Cooperative Association (NRECA), the American Public Power Association (APPA), the electricity industry, national laboratories, and universities to implement research and development activities.

Program Strategic Performance Goals

ER2-9: Distributed Energy Systems
Distributed Energy Storage Technology R&D activities will increase the share of new distributed energy electricity-generating capacity from 5 percent in 2000 to 7 percent in 2005. (Distributed energy activities funded by the Energy and Water Development Appropriation are part of a coordinated and complementary effort with distributed energy R&D activities funded by the Interior and Related Agencies Appropriation, which jointly contribute to this goal.)

Performance Indicator: MegaWatts of interconnected distributed energy-generating capacity (located at point of use and including distributed renewables such as PV and biomass).

Baselines:	1997: <15,000 megaWatts
	2002: ~20,000 megaWatts
Projected:	2005: ~25,000 megaWatts

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Target	FY 2003 Proposed Target
Advanced zinc-bromine battery systems successfully completed testing in a power-quality application in partnership with Detroit Edison Prototype reliability monitoring tools were installed in California to track reactive power, and at the North American Electric Reliability Council (NERC) to monitor load flow between control areas. First ballot action held on IEEE P1547 Draft Standard for Distributed Resources Interconnected with Electric Power Systems, and completed test plan for the standard.	In partnership with DOE, IEEE will publish draft P1547 Standard for Distributed Resources Interconnected with Electric Power Systems. Complete 300 hours testing of the ZBB advanced bromine battery system in partnership with Detroit Edison.	Complete draft UL1741 safety performance standard to cover interconnection equipment for all distributed resources. Field-Test 100kW lithium battery system for 700 hrs at a utility site. Install three prototype monitors and/or tools to benefit transmission reliability. Build and test for 150 hours a 10kW composite flywheel with superconducting bearings with Boeing.

Funding Schedule (dollars in thousands)

	FY2001 Appropriation	FY2002 Appropriation	FY2003 Request	$ Change	% Change
Technology Development	43,900	55,900	42,900	-13,000	-23.3%
End-Use System Integration	2,000	6,000	19,400	13,400	223%
Management and Planning	1,400	1,900	1,600	-300	-15.8%
Total, Distributed Energy Resources	47,300	63,800	63,900	-100	0%

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2.0 Technology Profiles

Biopower

Technology Description

Biopower, also called biomass power, is the generation of electric power from biomass resources – now usually urban waste wood, crop and forest residues; and, in the future, crops grown specifically for energy production. Biopower reduces most emissions (including emissions of greenhouse gases-GHGs) compared with fossil fuel-based electricity. Since biomass absorbs CO_2 as it grows, the entire biopower cycle of growing, converting to electricity, and regrowing biomass can result in very low CO_2 emissions. Through the use of residues, biopower systems can even represent a net sink for GHG emissions by avoiding methane emissions that would result from landfilling of the unused biomass.

Representative Technologies for Conversion of Feedstock to Fuel for Power and Heat

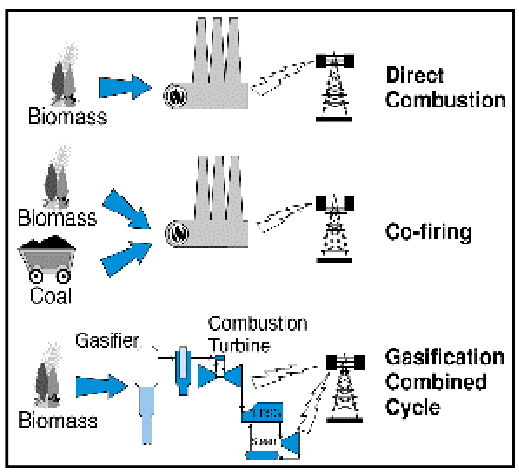
- *Homogenization* is a process by which feedstock is made physically uniform for further processing or for combustion. (includes chopping, grinding, baling, cubing, and pelletizing)
- *Gasification* (via pyrolysis, partial oxidation, or steam reforming) converts biomass to a fuel gas that can be substituted for natural gas in combustion turbines or reformed into H_2 for fuel cell applications.
- *Anaerobic digestion* produces biogas that can be used in standard or combined heat and power (CHP) applications. Agricultural digester systems use animal or agricultural waste. Landfill gas also is produced anaerobically.
- *Biofuels production for power and heat* provides liquid-based fuels such as methanol, ethanol, hydrogen, or biodiesel.

Representative Technologies for Conversion of Fuel to Power and Heat

- Direct combustion systems burn biomass fuel in a boiler to produce steam that is expanded in a Rankine Cycle prime mover to produce power.
- Cofiring substitutes biomass for coal or other fossil fuels in existing coal-fired boilers.
- Biomass or biomass-derived fuels (e.g. syngas, ethanol, biodiesel) also can be burned in combustion turbines (Brayton cycle) or engines (Otto or Diesel cycle) to produce power.
- When further processed, biomass-derived fuels can be used by fuels cells to produce electricity

System Concepts

- CHP applications involve recovery of heat for steam and/or hot water for district energy, industrial processes, and other applications.
- Nearly all current biopower generation is based on **direct combustion** in small, biomass-only plants with relatively low electric efficiency (20%), although total system efficiencies for CHP can approach 90%. Most biomass direct-combustion generation facilities utilize the basic Rankine cycle for electric-power generation, which is made up of the steam generator (boiler), turbine, condenser, and pump.
- For the near-term, **cofiring** is the most cost-effective of the power-only technologies. Large coal steam plants have electric efficiencies near 33%. The highest levels of coal cofiring (15% on a heat input basis) require separate feed preparation and injection systems.
- Biomass **gasification combined cycle** plants promise comparable or higher electric efficiencies (> 40%) using only biomass because they involve gas turbines (Brayton cycle), which are more efficient than Rankine cycles. Other technologies being developed include integrated gasification/fuel cell and biorefinery concepts.



Technology Applications

• The existing biopower sector, nearly 1,000 plants, is mainly comprised of direct-combustion plants, with an additional small amount of cofiring (six operating plants). Plant size averages 20 MW_e, and the biomass-to-electricity conversion efficiency is about 20%. Grid-connected electrical capacity has increased from less than 200 MW_e in 1978 to over 6500 MW_e in 2000. More than 75% of this power is generated in the forest products industry's CHP applications for process heat. Wood-fired systems account for close to 95% of this capacity. In addition, about 3,300 MW_e of municipal solid waste and landfill gas generating capacity exists. Recent studies estimate that on a life-cycle basis, existing biopower plants represent an annual net carbon sink of 4 MMTCe. Prices generally range from 8¢/kWh to 12¢/kWh.

Current Status

• CHP applications using a waste fuel are generally the most cost-effective biopower option. Growth is limited by availability of waste fuel and heat demand.
• Biomass cofiring with coal ($50 - 250/kW of biomass capacity) is the most near-term option for large-scale use of biomass for power-only electricity generation. Cofiring also reduces sulfur dioxide and nitrogen oxide emissions. In addition, when cofiring crop and forest-product residues, GHG emissions are reduced by a greater percentage (e.g. 23% GHG emissions reduction with 15% cofiring).
• Biomass gasification for large-scale (20 - 100MW_e) power production is being commercialized. It will be an important technology for cogeneration in the forest-products industries (which project a need for biomass and black liquor CHP technologies with a higher electric-thermal ratio), as well as for new baseload capacity. Gasification also is important as a potential platform for a biorefinery.
• Small biopower and biodiesel systems have been used for many years in the developing world for electricity generation. However, these systems have not always been reliable and clean. DOE is developing systems for village-power applications and for developed-world distributed generation that are efficient, reliable, and clean. These systems range in size from 3kW to 5MW and will begin field verification in the next 1-3 years.
• Current companies include:

Future Energy Resources, Inc. (FERCO)	Foster Wheeler
Energy Products of Idaho	PRM Energy Systems

Technology History

• In the latter part of the 19th century, wood was the primary fuel for residential, commercial, and transportation uses. By the 1950s, other fuels had supplanted wood. In 1973, wood use had dropped to 50 million tons per year.
• At that point, the forest products and pulp and paper industries began to use wood with coal in new plants and switched to wood-fired steam power generation.
• The Public Utility Regulatory Policies Act (PURPA) of 1978 stimulated the development of nonutility cogeneration and small-scale plants, leading to 70% self-sufficiency in the wood processing and pulp-and-paper sectors.
• As incentives were withdrawn in the late 1980s, annual installations declined from just more than 600 MW in 1989, to 300-350MW in 1990.
• There are now nearly 1,000 wood-fired plants in the United States, with about two-thirds of those providing power (and heat) for on-site uses only.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for Biomass Direct-fired and Gasification configurations are projected to be:

	2000	2010	2020
Direct-fired	7.5	7.0	5.8
Gasification	6.7	6.1	5.4

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496.

- R&D Directions include:

Gasification – This technology requires extensive field verification in order to be adopted by the relatively conservative utility and forest-products industries, especially to demonstrate integrated operation of biomass gasifier with advanced-power generation (turbines and/or fuel cells). Integration of gasification into a biorefinery platform is a key new research area.

Small Modular Systems – Small-scale systems for distributed or minigrid (for premium or village power) applications will be increasingly in demand.

Cofiring – The DOE biopower program is moving away from research on cofiring, as this technology has reached a mature status. However, continued industry research and field verifications are needed to address specific technical and nontechnical barriers to cofiring. Future technology development will benefit from finding ways to better prepare, inject, and control biomass combustion in a coal-fired boiler. Improved methods for combining coal and biomass fuels will maximize efficiency and minimize emissions. Systems are expected to include biomass cofiring up to 5% of natural gas combined-cycle capacity.

Biomass

Market Data

Cumulative Generating Capability, by Type (MW)	Source: *Energy Information Administration, Annual Energy Outlooks for 1998-2002, Table A17, and Renewable Resources in the U.S. Electricity Supply, 1993, Table 4, and world data from United Nations Development Program, World Energy Assessment, 2000, Table 7.25.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S. Electric Generators									
Municipal Solid Waste*				2,870	3,410	2,490	2,560	2,750	2,840
Wood and Other Biomass				1,910	1,640	1,760	1,460	1,370	1,390
U.S. Cogenerators									
Municipal Solid Waste*				410	460	520	700	510	510
Wood and Other Biomass				5,350	5,450	6,000	4,640	5,260	5,260
U.S. Total									
Municipal Solid Waste*			2,000	3,280	3,870	3,010	3,260	3,260	3,350
Wood and Other Biomass			6,000	7,260	7,090	7,760	6,100	6,630	6,650
Biomass Total			8,000	10,540	10,960	10,770	9,360	9,890	10,000
Rest of World Total**							30,000		
World Total							40,000		

* Municipal Solid Waste includes Landfill Gas

** Number derived from subtracting U.S. total from the world total. Figures may not add due to rounding.

U.S. Annual Installed Generating Capability, by Type (MW)	Source: *Renewable Electric Plant Information System (REPiS), Version 5, NREL, 2001.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Agricultural Waste[1]	22.6	20.1		4.0		21.6			
Biogas[2]	0.1	55.6	49.8	17.5	73.2	95.6	91.1	107.6	
Municipal Solid Waste[3]	50.0	117.2	260.3	94.5				22.0	
Wood Residues[4]	260.4	255.4	347.9	66.5	91.6	40.0	90.3	13.0	
Total	333.0	448.3	658.0	182.5	164.8	157.2	181.4	142.6	

U.S. Cumulative Generating Capability, by Type* (MW)	Source: *Renewable Electric Plant Information System (REPiS), Version 5, NREL, 2001.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Agricultural Waste[1]	40	92	165	351	351	373	373	373	
Biogas[2]	18	114	356	522	595	691	782	889	
Municipal Solid Waste[3]	263	697	2,172	2,916	2,916	2,916	2,916	2,938	
Wood Residues[4]	3,576	4,935	6,371	7,317	7,409	7,449	7,539	7,552	
Total	3,897	5,837	9,064	11,106	11,270	11,428	11,609	11,752	

* There are an additional 65.45 MW of Ag Waste, .945 MW of Bio Gas, 32.1 MW of MSW and 483.31 MW of Wood Residues that are not accounted for here because they have no specific online date.

[1]Agricultural residues, cannery wastes, nut hulls, fruit pits, nut shells

[2]Biogas, alcohol (includes butahol, ethanol, and methanol), bagasse, hydrogen, landfill gas, livestock manure, wood gas (from wood gasifier)

[3]Municipal solid waste (includes industrial and medical), hazardous waste, scrap tires, wastewater sludge, refused-derived fuel

[4]Timber and logging residues (Includes tree bark, wood chips, saw dust, pulping liquor, peat, tree pitch, wood or wood waste)

Generation from Cumulative Capacity, by Type (Billion kWh)	Source: *Energy Information Administration, Annual Energy Outlooks for 1998-2002, Table A17, and Renewable Resources in the U.S. Electricity Supply, 1993, Table 4, and world data from United Nations Development Program, World Energy Assessment, 2000, Table 7.25.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S. Electric Generators									
Municipal Solid Waste*				18.7	14.2	17.7	18.9	18.0	20.2
Wood and Other Biomass				7.1	4.3	6.9	6.5	7.5	8.4
U.S. Cogenerators									
Municipal Solid Waste*				2.0	1.8	3.0	3.9	3.2	3.3
Wood and Other Biomass				34.9	32.7	37.1	27.2	30.0	29.6
U.S. Total									
Municipal Solid Waste*			10.0	20.7	16.0	20.7	22.8	21.2	23.4
Wood and Other Biomass			31.0	42.0	37.0	44.0	33.7	37.5	38.0
Biomass Total			41.0	62.7	53.0	64.7	56.4	58.7	61.4
Rest of World Total**							104		
World Total							160		

* Municipal Solid Waste includes Landfill Gas

** Number derived from subtracting U.S. total from the world total. Figures may not add due to rounding.

U.S. Generation from Cumulative Capacity, by Type (Billion kWh)	Source: *Energy Information Administration, Monthly Energy Review, January 2002, Table 7.2.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Waste**			13.2	20.3	20.7	20.6	21.3	27.1	24.6
Wood*			30.4	36.4	36.8	34.2	31.8	37.6	39.5
Total Biomass			43.6	56.7	57.5	54.8	53.1	64.7	64.1

* Wood includes wood, wood waste, black liquor, red liquor, spent sulfite liquor, wood sludge, peat, railroad ties, and utility poles.

** Waste includes municipal solid waste, landfill gas, methane, digester gas, liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solid byproducts, tires, agricultural byproducts, closed loop biomass, fish oil

U.S. Annual Energy Consumption for Electricity Generation (Quadrillion Btu)	Source: *Energy Information Administration, Renewable Energy Annual 2000 (1995-1999), Table 3, and Energy Information Administration, Renewable Energy Annual 1995 (1990), Table 3.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Industrial Sector				0.567	0.574	0.547	0.528	0.576	
Electric-Utility Sector				0.017	0.020	0.021	0.021	0.021	
Electric-Power Industry				0.584	0.594	0.567	0.548	0.596	
Total				1.168	1.188	1.135	1.097	1.193	

Technology Performance

Source: Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 (this document is currently being updated by DOE and the values most likely will change).

Efficiency		**1980**	**1990**	**1995***	**2000**	**2005**	**2010**	**2015****	**2020**
Capacity Factor (%)	Direct-fired			80.0	80.0	80.0	80.0	80.0	80.0
	Cofired			85.0	85.0	85.0	85.0	85.0	85.0
	Gasification			80.0	80.0	80.0	80.0	80.0	80.0
Efficiency (%)	Direct-fired			23.0	27.7	27.7	27.7	30.8	33.9
	Cofired			32.7	32.5	32.5	32.5	32.5	32.5
	Gasification			36.0	36.0	37.0	37.0	39.3	41.5
Net Heat Rate (kJ/kWh)	Direct-fired			15,280	13,000	13,000	13,000	11,810	10,620
	Cofired			11,015	11,066	11,066	11,066	11,066	11,066
	Gasification			10,000	10,000	9,730	9,730	9,200	8,670

Cost		**1980**	**1990**	**1995***	**2000**	**2005**	**2010**	**2015**	**2020**
Total Capital Cost ($/kW)	Direct-fired			1,965	1,745	1,510	1,346	1,231	1,115
	Cofired***			272	256	241	230	224	217
	Gasification			2,102	1,892	1,650	1,464	1,361	1,258
Feed Cost ($/GJ)	Direct-fired			2.50	2.50	2.50	2.50	2.50	2.50
	Cofired***			-0.73	-0.73	-0.73	-0.73	-0.73	-0.73
	Gasification			2.50	2.50	2.50	2.50	2.50	2.50
Fixed Operating Cost ($/kW-yr)	Direct-fired			73.0	60.0	60.0	60.0	54.5	49.0
	Cofired***			10.4	10.1	9.8	9.6	9.5	9.3
	Gasification			68.7	43.4	43.4	43.4	43.4	43.4

		1980	1990	1995*	2000	2005	2010	2015	2020
Variable Operating Costs ($/kWh)	Direct-fired			0.009	0.007	0.007	0.007	0.006	0.006
	Cofired***			-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
	Gasification			0.004	0.004	0.004	0.004	0.004	0.004
Total Operating Costs ($/kWh)	Direct-fired			0.055	0.047	0.047	0.047	0.043	0.039
	Cofired***			-0.008	-0.008	-0.008	-0.009	-0.009	-0.009
	Gasification			0.040	0.036	0.036	0.036	0.034	0.033
Levelized Cost of Energy ($/kWh)	Direct-fired			0.087	0.075		0.070		0.058
	Cofired***			N/A	N/A	N/A	N/A	N/A	N/A
	Gasification			0.073	0.067		0.061		0.054

* Data is for 1997, the base year of the Renewable Energy Technology Characterizations analysis.

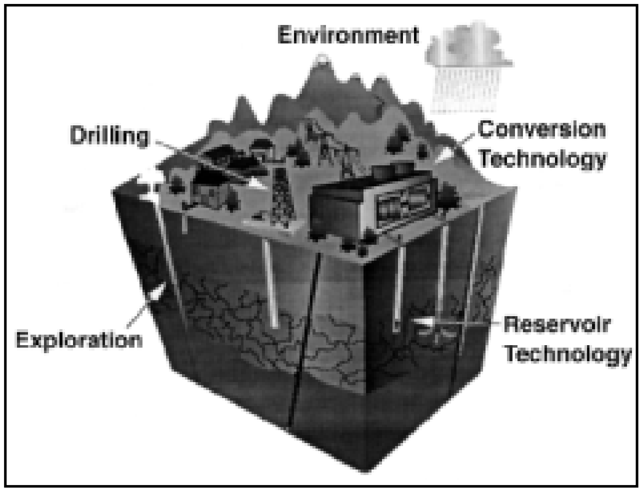
** Number derived by interpolation.

*** Note cofired cost characteristics represent only the biomass portion of costs for capital and incremental costs above conventional costs for Operations & Maintenance (O&M), and assume $9.14/dry tonne biomass and $39.09/tonne coal, a heat input from biomass at 19,104 kJ/kg, and that variable O&M includes an SO_2 credit valued at $110/tonne SO_2. No cofiring COE is reported in the *RETC*.

Geothermal Energy

Technology Description

Geothermal energy is thermal energy from within the earth. Hot water and steam are used to produce electricity or applied directly for space heating and industrial processes. There is potential to use geothermal energy to recover minerals and metals present in the geothermal brine.



System Concepts

- Geophysical, geochemical, and geological exploration locate permeable hot reservoirs to drill.
- Wells are drilled into the reservoirs.
- Well fields and distribution systems allow the hot geothermal fluids to move to the point of use, and are injected back to the earth.
- Steam turbines using natural steam or hot water flashed to steam, and binary turbines produce mechanical power that is converted to electricity.
- Direct applications utilize the thermal energy directly, for heating, without conversion to another form of energy.

Representative Technologies

- Dry-steam plants, which use geothermal steam to spin turbines;
- Flash-steam plants, which pump deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines.
- Binary-cycle plants, which use moderately hot geothermal water to heat a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to flash to vapor, which then drives the turbines.
- Exploration technologies for the identification of fractures and geothermal reservoirs; drilling to access the resource; geoscience and reservoir testing and modeling to optimize production and predict useful reservoir lifetime.

Technology Applications

- Mile-or-more-deep wells can be drilled into underground reservoirs to tap steam and very hot water that drive turbines and electricity generators. Because of economies of scale, geothermal power plants supply power directly to the grid, typically operating as baseload plants.
- Another use is direct applications to use the heat from geothermal fluids without conversion to electricity. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii, but some eastern states have geothermal resources that are used for direct applications. Hot water near the Earth's surface can be piped directly into facilities and used to heat buildings, grow plants in greenhouses, dehydrate onions and garlic, heat water for fish farming, and pasteurize milk. Some cities pipe the hot water under roads and sidewalks to melt snow. District heating systems use networks of piped hot water to heat many buildings in a community.
- The recovery of minerals and metals from geothermal brine can add value to geothermal-power projects

Current Status

- Hydrothermal reservoirs provide the heat for about 2100 MW of operating generating capacity in the United States at 18 resource sites. Another 700 MW of capacity at The Geysers was shut down.
- Three types of power plants are operating today: dry steam, flash steam, and binary.
- Worldwide installed capacity stands at about 8000 MW.
- The United States has a resource base capable of supplying heat for 40 GW of electrical capacity at costs competitive with conventional systems.
- Hydrothermal reservoirs are being used to produce electricity with an online availability of 97%; advanced energy conversion technologies are being implemented to improve plant thermal efficiency.
- Direct applications capacity is about 600 MW_t in the United States.
- Direct-use applications are successful, but require colocation of a quality heat source and need.
- More than 20 states use the direct use of geothermal energy, including Georgia and New York.
- Current leading geothermal technology companies include the following:

Calpine Corporation
Caithness Energy
Cal Energy Company (a subsidiary of Mid American Energy Holding Company)
Ormat International, Inc.

Technology History

- The use of geothermal energy as a source of hot water for spas dates back thousands of years.
- In 1892, the world's first district heating system was built in Boise, Idaho, as water was piped from hot springs to town buildings. Within a few years, the system was serving 200 homes and 40 downtown businesses. Today, the Boise district heating system continues to flourish. Although no one imitated this system for nearly 70 years, there are now 17 district heating systems in the United States and dozens more around the world.
- United States' first geothermal power plant went into operation in 1922 at The Geysers in California. The plant was 250 kW, but fell into disuse.
- In 1960, the country's first large-scale geothermal electricity-generating plant began operation. Pacific Gas and Electric operated the plant, located at The Geysers. The resource at the Geysers is dry steam. The first turbine produces 11 megawatts (MW) of net power and operated successfully for more than 30 years.
- In 1979, the first electrical development of a water-dominated geothermal resource occurred at the East Mesa field in the Imperial Valley in California.
- In 1980, UNOCAL built the country's first flash plant, generating 10 MW at Brawley, California.
- In 1981, with a supporting loan from DOE, Ormat International, Inc., successfully demonstrated binary technology in the Imperial Valley of California. This project established the technical feasibility of larger-scale commercial binary power plants. The project was so successful that Ormat repaid the loan within a year.
- By the mid 1980s, electricity was being generated by geothermal power in four western states: California, Hawaii, Utah, and Nevada.
- In the 1990s, the U.S. geothermal industry focused its attention on building power plants overseas, with major projects in Indonesia and the Philippines.
- In 1997, a pipeline began delivering treated municipal wastewater and lake water to The Geysers steamfield in California, increasing the operating capacity by 70 MW.
- In 2000, DOE initiated its GeoPowering the West program to encourage development of geothermal resources in the western United States by reducing nontechnical barriers.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for the two major future geothermal energy configurations are projected to be:

	2000	2010	2020
Hydrothermal Flash	3.0	2.4	2.1
Hydrothermal Binary	3.6	2.9	2.7

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496.

- New approaches to utilization will be developed, which increase the domestic resource base by a factor of 10.
- Improved methodologies will be developed for predicting reservoir performance and lifetime.
- Advances will be made in finding and characterizing underground permeability and developing low-cost, innovative drilling technologies.
- Further R&D will reduce capital and operating costs and improve the efficiency of geothermal conversion systems.
- Heat recovery methods will be developed that allow the use of geothermal areas that are deeper, less permeable, or dryer than those currently considered as resources.

Geothermal

Market Data

Annual Installed Electric Capacity (MW_e)

Source: *Renewable Energy Project Information System (REPiS), Version 5, NREL, 2001.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S.	251.0	352.9	48.6		36.0				49.0
Rest of World									
World Total									

Cumulative Installed Electric Capacity (MW_e)

Source: Renewable Energy Project Information System (REPiS), Version 5, NREL, 2001, and *Renewable Energy World*/July-August 2000, page 123, Table 1.

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S.	802	1,698	2,540	2,684	2,720	2,720	2,720	2,720	2,769
Rest of World	1,298	3,066	3,293	4,114					5,206
World Total	2,100	4,764	5,832	6,797					7,974

Annual Generation from Cumulative Installed Electric Capacity (billion kWh)

Source: EIA,REA 2000- Table 4 (1995-99), EIA REA 1995 (1990) and, Renewable Energy World/July-August 2000, page 126, Table 2.

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S.									
Electric Power Industry			15.5	14.4	15.1	14.6	14.7	16.8	
Imports			0.58	0.88	0.65	0.02	0.05	0.03	
Electric Geothermal Total			16.1	15.2	15.8	14.6	14.8	16.8	
Rest of World									
World Total	14	17	19.0	20.0					49.3

Annual U.S. Geothermal Heat Pump Shipments, by type (units)	Source: Energy Information Administration - REA 2000- Table 35.								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
ARI-320				4,696	4,697	7,772	10,510	13,236	
ARI-325/330				26,800	25,697	28,335	26,042	34,271	
Other non-ARI Rated				838	991	1,327	1,714	1,655	
Totals				32,334	31,385	37,434	38,266	49,162	

Capacity of U.S. Heat Pump Shipments* (Rated Tons)	Source: Energy Information Administration - REA 2000- Table 36.								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
ARI-320				13,120	15,060	24,708	35,776	33,163	
ARI-325/330				113,925	92,819	110,186	98,912	149,303	
Other non-ARI Rated				3,935	5,091	6,662	6,758	6,070	
Totals				130,980	112,970	141,556	141,446	188,536	

* One Rated Ton of Capacity equals 12,000 Btu's.

Annual U.S. Geothermal Heat Pump Shipments by Customer Type and Model Type (units)	Source: *Energy Information Administration - REA 2000- Table 38, REA 1999- Table 38, and REA 1998- Table 40.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Exporter					2,276	226	109	6,172	
Wholesale Distributor					21,444	29,181	14,377	9,193	
Retail Distributor					8,336	829	3,222	2,555	
Installer					18,762	25,302	18,429	24,917	
End-User					689	657	994	66	
Others					13	1,727	1,135	6,259	
Total					51,520	57,922	38,266	49,162	

Annual U.S. Geothermal Heat Pump Shipments by Export & Census Region (units)	Source: *Energy Information Administration - REA 2000- Table 37, REA 1999- Table 37, and REA 1998- Table 39.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Export					4,090	2,427	481	6,303	
Midwest					11,874	13,402	12,240	13,112	
Northeast					6,417	9,280	5,403	6,044	
South					25,302	26,788	16,195	20,935	
West					3,837	6,025	3,947	2,768	
Total					51,520	57,922	38,266	49,162	

Cumulative Installed Capacity	Source: *EIA - AEO 1997-2002, Table A17, Renewable Resources in the U.S. Electric Supply, 1993- Table 4, World Totals from UNDP World Energy Assessment 2000, Tables 7.20 and 7.22, and Renewable Energy World/July-August 2000.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Electricity (MW_e)									
U.S.			2,575	3,020	3,000	2,870	2,860	2,790	2,850
Rest of World			3,292	3,778		5,130	5,379		
World Total			5,867	6,798		8,000	8,239		
Direct-Use Heat (MW_{th})									
U.S.							1,910		
Rest of World							9,090		
World Total	1,950	7,072	8,064	8,664		10,400	11,000		17,175

Annual Generation from Cumulative Installed Capacity	Source: *EIA - AEO 1997-2002, Table A17, Renewable Resources in the U.S. Electric Supply, 1993- Table 4, and World Totals from UNDP World Energy Assessment 2000, Tables 7.20 and 7.22.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Electricity (Billion kWh_e)									
U.S.			15.0	14.7	15.4	14.6	15.1	15.4	13.5
Rest of World						29.2	30.9		
World Total						43.8	46.0		
Direct-Use Heat (billion kWh_{th})									
U.S.							4.0		
Rest of World							36.0		

World Total		24.0		31.3		38.2	40.0		51.4
Installed Capacity and Power Generation/Energy Production from Installed Capacity	Source: *Lund and Freeston, World-Wide Direct Uses of Geothermal Energy 2000, Lund and Boyd, Geothermal Direct-Use in the United States Update: 1995-1999, J. Lund, World Status of Geothermal Energy Use Overview 1995-1999, Sifford and Blommquist, Geothermal Electric Power Production in the United States: A Survey and Update for 1995-1999, and G. Huttrer, The Status of World Geothermal Power Generation 1995-2000. Proceedings of the World Geothermal Congress 2000, Kyushu-Tohoku, Japan, May 28- June10, 2000.*								
Cumulative Installed Capacity									
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Electricity (MW_e)									
U.S.				2,369	2,343	2,314	2,284	2,293	2,228
Rest of World				4,464					5,746
World Total	3,887	4,764	5,832	6,833					7,974
Direct-Use Heat* (MW_{th})									
U.S.									4,200
Rest of World									12,975
World Total	1,950	7,072	8,064	8,664				16,209	17,175
Annual Generation/Energy Production from Cumulative Installed Capacity									
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Electricity (Billion kWh_e)									
U.S.				14.4	15.1	14.6	14.7	15.0	15.5
Rest of World									33.8
World Total									49.3
Direct-Use Heat* (TJ)									
U.S.				13,890				20,302	21,700
Rest of World				98,551				141,707	
World Total		86,249		112,441				162,009	185,139

* Direct-use heat includes geothermal heat pumps as well as traditional uses. Geothermal heat pumps account for 1854 MW_{th} (14,617 TJ) in 1995 and 6849 MW_{th} (23,214 TJ) in 1999 of the world totals and 3600 MW_{th} (8,800 TJ) in 2000 of the U.S. total. Conversion of GWh to TJ is done at 1TJ = 0.2778 GWh.

Annual Generation from Cumulative Installed Capacity (Billion kWh)	Source: *EIA, Monthly Energy Review, December 2001- Table 7.2 Electricity Net Generation.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	5.1	9.3	15.8	14.4	15.1	14.6	14.7	15.0	14.2
Rest of World									
World Total									

Annual Geothermal Energy Consumption for Electric Generation (Quadrillion Btu)	Source: *EIA, Monthly Energy Review, Electric Power Sector Energy Consumption 1973-2000, http://tonto.eia.doe.gov/mer/.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S. Total	0.11	0.198	0.344	0.319	0.331	0.306	0.31	0.316	0.298
Rest of the World									
World Total									

Annual Geothermal Energy Consumption (Quadrillion Btu)	Source: *EIA, Monthly Energy Review, Energy Consumption by Source 1973-2000, http://tonto.eia.doe.gov/mer/.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S. Total	0.11	0.198	0.355	0.333	0.346	0.322	0.328	0.335	0.319
Rest of the World									
World Total									

Technology Performance

		1980	1990	1995	2000	2005	2010	2015	2020
Efficiency	Source: Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 (this document is currently being updated by DOE and the values most likely will change).								
		1980	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capacity Factor (%)	Flashed Steam			89	92	93	95	96	96
	Binary			89	92	93	95	96	96
	Hot Dry Rock			80	81	82	83	84	85
Cost									
		1980	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capital Cost ($/kW)	Flashed Steam			1,444	1,372	1,250	1,194	1,147	1,100
	Binary			2,112	1,994	1,875	1,754	1,696	1,637
	Hot Dry Rock			5,519	5,176	4,756	4,312	3,794	3,276
Fixed O&M ($/kW-yr)	Flashed Steam			96.4	87.1	74.8	66.3	62.25	58.2
	Binary			87.4	78.5	66.8	59.5	55.95	52.4
	Hot Dry Rock			219	207	191	179	171	163

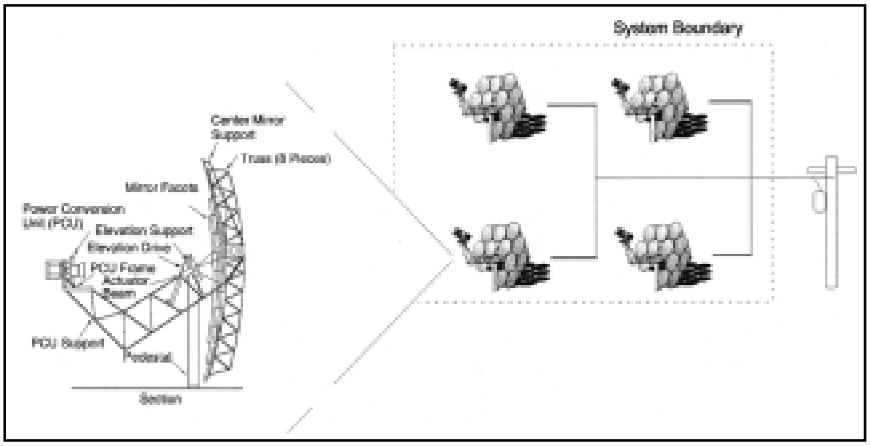
Concentrating Solar Power

Technology Description

Concentrating Solar Power (CSP) systems concentrate solar energy 50 to 5,000 times to produce high-temperature thermal energy, which is used to produce electricity for distributed- or bulk-generation power applications.

System Concepts

- In CSP systems, highly reflective sun-tracking mirrors produce temperatures of 400°C to 800°C in the working fluid of a receiver; this heat is used in conventional heat engines (steam or gas turbines or Stirling engines) to produce electricity at system solar-to-electric efficiencies of up to 30%. Systems using advanced photovoltaics (PV) cells may achieve efficiencies greater than 35%.



Representative Technologies

- A parabolic trough system focuses solar energy on a linear oil-filled receiver, which collects heat to generate steam and power a steam turbine. When the sun is not shining, steam can be generated with fossil fuel to meet utility needs. Plant sizes can range from 10 MWe to 100 MWe.
- A power tower system uses many large heliostats to focus the solar energy onto a tower-mounted central receiver filled with a molten-salt working fluid that produces steam. The hot salt can be stored efficiently to allow power production to match utility demand even when the sun is not shining. Plant size can range from 30 MWe to 200 MWe.
- A dish/engine system (see diagram above) uses a dish-shaped reflector to power a small Stirling or Brayton engine/generator or a high-concentrator PV module mounted at the focus of the dish. Dishes are 2 to 25 kW in size, can be used individually or in small groups, and are easily hybridized with fossil fuel.

Technology Applications

- Concentrating solar power systems can be sized for village power (10 kilowatts) or grid-connected applications (up to 100 megawatts). Some systems use thermal storage during cloudy periods or at night. Others can be combined with natural gas such that the resulting hybrid power plants can provide higher-value, dispatchable power.

- To-date, the primary use of CSP systems has been for bulk power supply to the southwestern grid. However, these systems were installed under very attractive power purchase rates that are not generally available today. With one of the best direct normal insolation resources anywhere on Earth, the southwestern states are still positioned to reap large and, as yet, largely uncaptured economic benefits from this important natural resource. California, Nevada, Arizona, and New Mexico are each exploring policies that will nurture the development of their solar-based industries.

- In addition to the concentrating solar power projects under way in this country, a number of projects are being developed in India, Egypt, Morocco, and Mexico. In addition, independent power producers are in the early stages of design and development for potential parabolic trough and/or power tower projects in Greece (Crete) and Spain. Given successful deployment of systems in one or more of these initial markets, several domestic project opportunities are expected to follow.
- Distributed-systems deployment opportunities are emerging for dish-engine systems. Many states are adopting green power requirements in the form of "portfolio standards" and renewable energy mandates. While the potential markets in the United States are large, the size of developing worldwide markets is immense. The International Energy Agency projects an increased demand for electrical power worldwide more than doubling installed capacity. More than half of this is in developing countries and a large part is in areas with good solar resources, limited fossil fuel supplies, and no power distribution network. The potential payoff for dish/engine system developers is the opening of these immense global markets for the export of power generation systems.

Current Status

- CSP technology is generally still too expensive to compete in widespread domestic markets without significant subsidies. Consequently, RD&D goals are to reduce costs of CSP systems to 5¢/kWh to 8¢/kWh with moderate production levels within five years, and below 5c/kWh at high production levels in the long term.
- Nine parabolic trough plants, with a total rated capacity of 354 MWe, were installed in California between 1985 and 1991. Their continuing operation has demonstrated their ability to achieve commercial costs of about 12¢/kWh to 14¢/kWh.
- Solar Two, a 10-MWe pilot power tower with three hours of storage, also installed in California, provided technical information needed to scale up to a 30-100 MW commercial plant, the first of which is now being planned in Spain.
- A number of prototype dish/Stirling systems are currently operating in Nevada, Arizona, Colorado, and Spain. High levels of performance have been established; durability remains to be proven, although some systems have operated for more than 10,000 hours.
- The CSP industry includes 25 companies who design, sell, own, and/or operate energy systems and power plants based on the concentration of solar energy. CSP companies include energy utilities, independent power producers or project developers, equipment manufacturers, specialized development firms, and consultants. While some firms only offer CSP products, many offer related energy products and services. Four of the 25 are “Fortune 500 Companies.” Current companies include:

Duke Solar Energy, LLC
Nexant (a Bechtel Technology & Consulting Company)
The Boeing Company
KJC Operating Company
SunRay Corporation
Arizona Public Service Corporation
Spencer Management Associates
Kearney & Associates
Nagel Pump
Clever Fellows Innovative Consortium
Array Technologies
Concentrating Technologies
Ed Tek Inc.
Stirling Energy Systems
Science Applications International Corp.
STM Corporation
WGAssociates
Morse & Associates
United Innovations Inc.
Reflective Energies
Industrial Solar Technologies
Spectralab
Salt River Project
Energy Laboratories Inc.
Amonix

Technology History

Organized, large-scale development of solar collectors began in the United States in the mid-1970s under the Energy Research and Development Administration (ERDA) and continued with the establishment of the U.S. Department of Energy (DOE) in 1978.

Troughs:

- Parabolic trough collectors capable of generating temperatures greater than 500ºC (932 F) were initially developed for industrial process heat (IPH) applications. Acurex, SunTec, and Solar Kinetics were the key parabolic trough manufacturers in the United States during this period.
- Parabolic trough development also was taking place in Europe and culminated with the construction of the IEA Small Solar Power Systems (SSPS) Project/Distributed Collector System in Tabernas, Spain, in 1981. This facility consisted of two parabolic trough solar fields – one using a single-axis tracking Acurex collector and one the double-axis tracking parabolic trough collectors developed by M.A.N. of Munich, Germany.
- In 1982, Luz International Limited (Luz) developed a parabolic trough collector for IPH applications that was based largely on the experience that had been gained by DOE/Sandia and the SSPS projects.
- Southern California Edison (SCE) signed a power purchase agreement with Luz for the Solar Electric Generating System (SEGS) I and II plants, which came online in 1985. Luz later signed a number of Standard Offer (SO) power purchase contracts under the Public Utility Regulatory Policies Act (PURPA), leading to the development of the SEGS III through SEGS IX projects. Initially, the plants were limited by PURPA to 30 MW in size; later this limit was raised to 80 MW. In 1991, Luz filed for bankruptcy when it was unable to secure construction financing for its 10th plant (SEGS X).
- The 354 MWe of SEGS trough systems are still being operated today. Experience gained through their operation will allow the next generation of trough technology to be installed and operated much more cost-effectively.

Power Towers:

- A number of experimental power tower systems and components have been field-tested around the world in the past 15 years, demonstrating the engineering feasibility and economic potential of the technology.
- Since the early 1980s, power towers have been fielded in Russia, Italy, Spain, Japan, and the United States.
- In early power towers, the thermal energy collected at the receiver was used to generate steam directly to drive a turbine generator.
- The U.S.-sponsored Solar Two was designed to demonstrate the dispatchability provided by molten-salt storage and to provide the experience necessary to lessen the perception of risk from these large systems.
- U.S. Industry is currently pursuing a subsidized power tower project opportunity in Spain. This project, dubbed “Solar Tres,” represents a 4x scale-up of the Solar 2 design.

Dish/Engine Systems:

- Dish/engine technology is the oldest of the solar technologies, dating back to the 1800s when a number of companies demonstrated solar-powered steam Rankine and Stirling-based systems.
- Development of modern technology began in the late 1970s and early 1980s. This technology used directly illuminated, tubular solar receivers, a kinematic Stirling engine developed for automotive applications, and silver/glass mirror dishes. Systems, nominally rated at 25 kWe, achieved solar-to-electric conversion efficiencies of around 30 percent (still the world record to date). Eight prototype systems were deployed and operated on a daily basis from 1986 through 1988.
- In the early 1990s, Cummins Engine Company attempted to commercialize dish/Stirling systems

based on free-piston Stirling engine technology. Efforts included a 5 to 10 kWe dish/Stirling system for remote power applications, and a 25 kWe dish/engine system for utility applications. However, largely because of a corporate decision to focus on its core diesel-engine business, Cummins canceled their solar development in 1996. Technical difficulties with Cummins' free-piston Stirling engines were never resolved.

- Current dish/engine efforts are being continued by three U.S. industry teams - Science Applications International Corp. (SAIC) teamed with STM Corp., Boeing with Stirling Energy Systems, and WG Associates with Sunfire Corporation. SAIC and Boeing together have five 25kW systems under test and evaluation at utility, industry, and university sites in Arizona, California, and Nevada. WGA has two 10kW systems under test in New Mexico, with a third off-grid system being developed in 2002 on an Indian reservation for water-pumping applications.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for the three CSP configurations are projected to be:

	2000	2010	2020
Trough	9.5	5.4	4.4
Power Tower	9.5	4.8	3.6
Dish/Engine	17.9	6.1	5.5

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496 for Dish/Engine, and Program values for Trough and Power Tower.

- RD&D efforts are targeted to improve performance and lifetime, reduce manufacturing costs with improved designs, provide advanced designs for long-term competitiveness, and address barriers to market entry.
- Improved manufacturing technologies are needed to reduce the cost of key components, especially for first-plant applications where economies of scale are not yet available.
- Demonstration of Stirling engine performance and reliability in the field are critical to the success of dish/engine systems.
- DOE expects Dish/Stirling systems to be available by 2005, after deployment and testing of 1 MW (40 systems) during the next two years.
- Key DOE program activities are targeted to support the next commercial opportunities for these technologies, demonstrate improved performance and reliability of components and systems, reduce energy costs, and develop advanced systems and applications.
- The successful conclusion of Solar Two sparked worldwide interest in power towers. As Solar Two completed operations, an international consortium led by U.S. industry including Bechtel and Boeing (with technical support from Sandia National Laboratories), formed to pursue power tower plants worldwide, especially in Spain (where special solar premiums make the technology cost-effective), but also in Egypt, Morocco, and Italy. Their first commercial power tower plant is planned to be four times the size of Solar Two (about 40 MW equivalent, utilizing storage to power a 15MW turbine up to 24 hours per day).
- The World Bank's Solar Initiative is pursuing CSP technologies for less-developed countries. The World Bank considers CSP as a primary candidate for Global Environment Facility funding, which could total $1B to $2B for projects during the next two years.

Concentrating Solar Power

Market Data

U.S. Installations (electric only) — Source: *Renewable Energy Project Information System (REPiS), Version 5, NREL, 2001, and Renewable Energy Technology Characterizations, EPRI TR-109496.*

Cumulative (MW)	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	0	24	274	354	364	364	364	364	354
Power Tower	0	10	0	0	10	10	10	10	0
Trough	0	14	274	354	354	354	354	354	354
Dish/Engine	0	0	0	0	0	0	0.125	0.125	0.125

Annual Generation from Cumulative Installed Capacity (Billion kWh) — Source: EIA, AEO 1998-2002- Table A17, Renewable Resources in the Electric Supply, 1993- Table 4, and Monthly Energy Review, December 2001- Table 7.2.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.			0.63	0.82	0.90	0.89	0.89	0.87	0.87

Technology Performance

Efficiency — Source: *Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 (this document is currently being updated by DOE, and the values most likely will change), and TC revisions made by Hank Price of NREL for Trough technologies and Scott Jones of Sandia National Laboratory for Power Towers in 2001.*

		1980	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capacity Factor (%)	Power Tower			20.0	43.0	44.0	65.0	71.0	77.0
	Trough			34.0	33.3	41.7	51.2	51.2	51.2
	Dish			12.4	50.0	50.0	50.0	50.0	50.0
Solar to Electric Eff. (%)	Power Tower			8.5	15.0	16.2	17.0	18.5	20.0
	Trough			10.7	13.1	13.9	14.8	14.8	15.6
	Dish/Engine								

Cost*		1980	1990	1995	2000	2005	2010	2015	2020
Total ($/kWp)	Power Tower				1,747	1,294	965	918	871
	Trough			4,033	2,103	1,633	1,277	1,185	1,072
	Dish/Engine			12,576	5,191	2,831	1,365	1,281	1,197
Total ($/kWnameplate)	Power Tower				3,145	2,329	2,605	2,475	2,345
	Trough			4,033	3,154	2,988	2,766	2,568	2,323
	Dish/Engine			12,576	5,691	3,231	1,690	1,579	1,467
O&M ($/kWh)	Power Tower			0.171	0.018	0.006	0.005	0.004	0.004
	Trough			0.025	0.017	0.013	0.009	0.007	0.007
	Dish/Engine			0.210	0.037	0.023	0.011	0.011	0.011
Levelized Cost of Energy	Power Tower				0.101	0.066	0.051	0.044	0.038
($/kWh)	Trough			0.160	0.101	0.077	0.057	0.052	0.047
	Dish/Engine				0.179		0.061	0.058	0.055

* Cost data for trough and power tower technologies are from 2001 revisions (in 2001$). Dish/Engine data for $/kWp excludes costs of hybrid system and $/kWnameplate includes hybrid costs (in 1997$).

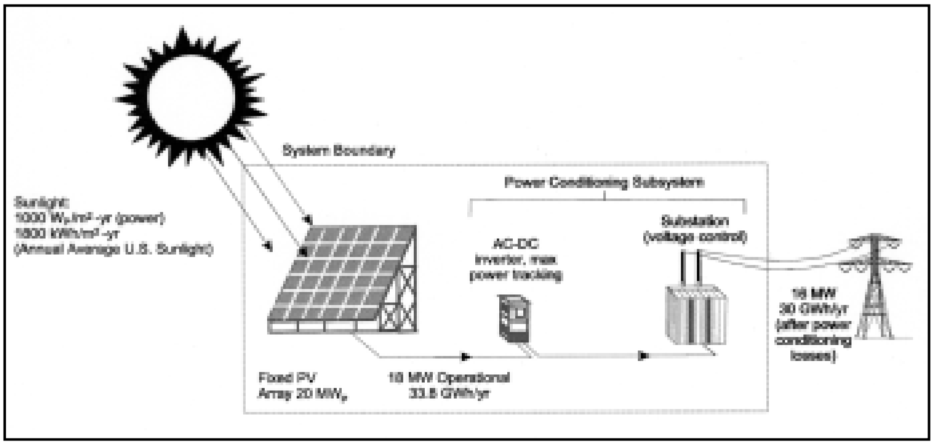
Photovoltaics

Technology Description

Photovoltaic (PV) arrays convert sunlight to electricity without moving parts and without producing fuel wastes, air pollution, or greenhouse gases (GHGs). Using solar PV for electricity and eventually transportation (from hydrogen production) will help reduce CO_2 worldwide.

System Concepts

- Flat-plate PV arrays use global sunlight; concentrators use direct sunlight. Modules are mounted on a stationary array or on single- or dual-axis sun trackers. Arrays can be ground-mounted or on all types of buildings and structures (e.g., see semi-transparent solar canopy, right). PV dc output can be conditioned into grid-quality ac electricity, or dc can be used to charge batteries or to split water to produce H_2.



Representative Technologies

- Flat-plate cells are either constructed from crystalline silicon cells, or from thin films using amorphous silicon. Other materials such as copper indium diselinide (CIS) and cadmium telluride also hold promise as thin-film materials. The vast majority of systems installed today are in flat-plate configurations where multiple cells are mounted together to form a module. These systems are generally fixed in a single position, but can be mounted on structures that tilt toward the sun on a seasonal basis, or on structures that roll east to west over the course of the day.
- Photovoltaic concentrator systems use optical concentrators to focus direct sunlight onto solar cells for conversion to electricity. A complete concentrating system includes concentrator modules, support and tracking structures, a power-processing center, and land. PV concentrator module components include solar cells, an electrically isolating and thermally conducting housing for mounting and interconnecting the cells, and optical concentrators. The solar cells in today's concentrators are predominantly silicon, although gallium arsenide-based (GaAs) solar cells may be used in the future because of their high-conversion efficiencies. The housing places the solar cells at the focus of the optical concentrator elements and provides means for dissipating excess heat generated in the solar cells. The optical concentrators are generally Fresnel lenses but also can be reflectors.

Technology Applications

- PV systems can be installed as either grid supply technologies or as customer-sited alternatives to retail electricity. As suppliers of bulk grid power, PV modules would typically be installed in large array fields ranging in total peak output from a few megawatts on up. Very few of these systems have been installed to-date. A greater focus of the recent marketplace is on customer-sited systems, which may be installed to meet a variety of customer needs. These installations may be residential-size systems of just one kilowatt, or commercial-size systems of several hundred kilowatts. In either case, PV systems meet customer needs for alternatives to purchased power, reliable power, protection from price escalation, desire for green power, etc. Interest is growing in the use of PV systems as part of the building structure or façade (“building integrated”). Such systems use PV modules designed to look like shingles, windows, or other common building elements.

• PV systems are expected to be used in the United States for residential and commercial buildings; distributed utility systems for grid support; peak power shaving, and intermediate daytime load following; with electric storage and improved transmission, for dispatchable electricity; and H_2 production for portable fuel.
• Other applications for PV systems include electricity for remote locations, especially for billions of people worldwide who do not have electricity. Typically, these applications will be in hybrid minigrid or battery-charging configurations.
• Almost all locations in the United States and worldwide have enough sunlight for PV (e.g., U.S. sunlight varies by only about 25% from an average in Kansas).
• Land area is not a problem for PV. Not only can PV be more easily sited in a distributed fashion than almost all alternatives (e.g., on roofs or above parking lots), a PV-generating station 140 km-by-140 km sited at an average solar location in the United States could generate all of the electricity needed in the country (2.5×10^6 GWh/year), assuming a system efficiency of 10% and an area packing factor of 50% (to avoid self-shading). This area (0.3% of U.S.) is less than one-third of the area used for military purposes in the United States.

Current Status

• The cost of PV-generated electricity has dropped 15- to 20-fold; and grid-connected PV systems currently sell for about \$5–\$10/W_p (20 to 50¢/kWh), including support structures, power conditioning, and land. They are highly reliable and last 20 years or longer.
• Crystalline silicon is widely used and the most commercially mature photovoltaic material. Thin-film PV modules currently in production include three based on amorphous silicon, cadmium telluride, and CIS alloys.
• About 288 MW of PV were sold in 2000 (more than \$2 billion worth); total installed PV is more than 1 GW. The U.S. world market share is about 26%. Annual market growth for PV has been about 25% as a result of reduced prices and successful global marketing. In recent years, sales growth has accelerated to almost 40% per year. Hundreds of applications are cost-effective for off-grid needs. Almost two-thirds of U.S.-manufactured PV is exported. However, the fastest growing segment of the market is grid-connected PV, such as roof-mounted arrays on homes and commercial buildings in the United States. California is subsidizing PV systems because it is considered cost-effective to reduce their dependence on natural gas, especially for peak daytime loads for air-conditioning, which matches PV output.
• Highest efficiency for wafers of single-crystal or polycrystalline silicon is 24%, and for commercial modules is 13%–15%. Silicon modules currently cost about \$2-\$3/W_p to manufacture.
• During the past two years, *world record* solar cell sunlight-to-electricity conversion efficiencies were set by federally funded universities, national laboratories, or industry in copper indium gallium diselenide (19% cells and 12% modules) and cadmium telluride (16% cells, 11% modules). Cell and module efficiencies for these technologies have increased more than 50% in the past decade. Efficiencies for commercial thin-film modules are 5%–11%. A new generation of thin-film PV modules is going through the high-risk transition to first-time and large-scale manufacturing. If successful, market share could increase rapidly.
• Highest efficiencies for single-crystal Si and multijunction gallium arsenide (GaAs)-alloy cells for concentrators are 25%–34%; and for commercial modules are 15%–17%. Prototype systems are being tested in the U.S. desert SW.
• Current leading PV companies in 2000 and associated production of cells/modules are listed below:

	U.S. Production (2000)	World Production
	MW	MW
BP/Amoco Solarex	22.0	41.0
Kyocera	-	42.0
Sharp	-	50.4
Siemens	28	28.0
Astropower	18.0	18.0
Sanyo	-	17.0
Photowatt	-	14.0
ASE (GMBH)	-	12.0
Solec Intl	-	-
Advanced PV Sys.	-	-
USSC	3.0	-
ASE Americas	6.0	-
Others	1.5	-
Total (for leading producers)	78.5	222.4

Source: PV News, Vol. 20, No. 2, Page 2

Technology History

- French physicist Edmond Becquerel first described the photovoltaic (PV) effect in 1839, but it remained a curiosity of science for the next three quarters of a century. At only 19, Becquerel found that certain materials would produce small amounts of electric current when exposed to light. The effect was first studied in solids, such as selenium, by Heinrich Hertz in the 1870s. Soon afterward, selenium PV cells were converting light to electricity at more than 1 percent efficiency. As a result, selenium was quickly adopted in the emerging field of photography for use in light-measuring devices.
- Major steps toward commercializing PV were taken in the 1940s and early 1950s, when the Czochralski process was developed for producing highly pure crystalline silicon. In 1954, scientists at Bell Laboratories depended on the Czochralski process to develop the first crystalline silicon photovoltaic cell, which had an efficiency of 4 percent. Although a few attempts were made in the 1950s to use silicon cells in commercial products, it was the new space program that gave the technology its first major application. In 1958, the U.S. Vanguard space satellite carried a small array of PV cells to power its radio. The cells worked so well that PV technology has been part of the space program ever since.
- Even today, PV plays an important role in space, supplying nearly all power for satellites. The commercial integrated circuit technology also contributed to the development of PV cells. Transistors and PV cells are made from similar materials and operate on similar physical mechanisms. As a result, advances in transistor research provided a steady flow of new information about PV cell technology. (Today, however, this technology transfer process often works in reverse, as advances in PV research and development are sometimes adopted by the integrated circuit industry.)
- Despite these advances, PV devices in 1970 were still too expensive for most "down-to-Earth" uses. But, in the mid-1970s, rising energy costs, sparked by a world oil crisis, renewed interest in making PV technology more affordable. Since then, the federal government, industry, and research organizations have invested billions of dollars in research, development, and production. A thriving industry now exists to meet the rapidly growing demand for photovoltaic products.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for PV are projected to be:

	2000	2010	2020
Utility-owned Residential (crystalline Si)	29.7	17.0	10.2
Utility-Scale Thin-Film	29.0	8.1	6.2
Concentrator	24.4	9.4	6.5

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496.
(Note that this document is currently being updated by DOE, and the values most likely will change).

- Crystalline Silicon - Most PV systems installed to-date have used crystalline silicon cells. That technology is relatively mature. In the future, cost-effectiveness will be achieved through incremental efficiency improvements, enhanced yields, and advanced lower-cost manufacturing techniques.
- Even though some thin-film modules are now commercially available, their real commercial impact is only expected to become significant during the next three to 10 years. Beyond that, their general use should occur in the 2005-2015 time frame, depending on investment levels for technology development and manufacture.
- Thin films using amorphous silicon, which are a growing segment of the U.S. market, have several advantages over crystalline silicon. It can be manufactured at lower cost, is more responsive to indoor light, and can be manufactured on flexible or low-cost substrates. Improved semiconductor deposition rates will reduce manufacturing costs in the future. Other thin-film materials will become increasingly important in the future. In fact, the first commercial modules using indium gallium diselinide thin-film devices were produced in 2000. Improved manufacturing techniques and deposition processes will reduce costs and help improve efficiency.
- Substantial commercial interest exists in scaling-up production of thin films. As thin films are produced in larger quantity, and as they achieve expected performance gains, they will become more economical for the whole range of applications.
- Multijunction cells with efficiencies of 38% at very high concentrations are being developed.
- Manufacturing research and supporting technology development hold important keys to future cost reductions. Large-scale manufacturing processes will allow major cost reductions in cells and modules. Advanced power electronics and non-islanding inverters will lessen barriers to customer adoption and utility interface.
- A unique multijunction GaAs-alloy cell developed at NREL was spun off to the space power industry, leading to a record cell (34%) and a shared R&D100 Award for NREL/Spectrolab in 2001. This device configuration is expected to dominate future space power for commercial and military satellites.

Photovoltaics

Market Data

PV Cell/Module Production (Shipments) Source: *PV News, Vol. 15, No. 2, Feb. 1996; Vol. 16, No. 2, Feb. 1997; and Vol. 20, No. 2, Feb. 2001, and [Paul Maycock, www.pvenergy.com]*

Annual (MW)	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
U.S.	3	8	15	35	39	51	54	61	75	105
Japan	1	10	17	16	21	35	49	80	129	171
Europe	0	3	10	20	19	30	34	40	61	88
Rest of World	0	1	5	6	10	9	19	21	23	32
World Total	4	23	47	78	89	126	155	201	288	396
Cumulative (MW)	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
U.S.	5	45	101	219	258	309	363	424	498	604
Japan	1	26	95	185	206	241	290	370	498	670
Europe	1	13	47	136	155	185	219	259	319	408
Rest of World	0	3	20	45	55	65	83	104	127	159
World Total	7	87	263	585	674	800	954	1,156	1,443	1,839
U.S. % of World Sales	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Annual	71%	34%	32%	44%	44%	41%	35%	30%	26%	27%
Cumulative	75%	52%	39%	37%	38%	39%	38%	37%	35%	33%

Annual Capacity (Shipments retained, MW)* Source: *Strategies Unlimited*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	1.4	4.2	5.1	8.4	9.2	10.5	13.6	18.4	21.3
Total World	3	15	39	68	79	110	131	170	246

*Excludes indoor consumer (watches/calculators).

Cumulative Capacity (Shipments retained, MW)*	Source: *Strategies Unlimited*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	3	23	43	76	85	96	109	128	149
Total World	6	61	199	474	552	663	794	964	1,210

*Excludes indoor consumer (watches/calculators).

U.S. Shipments (MW)	Source: *Energy Information Administration, Annual Energy Review, 2000, Tables 10.5 and 10.6, and REA 2000, Table 24.*								
Annual Shipments	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total		5.8	13.8	31.1	35.5	46.4	50.6	76.8	88.2
Imports		0.3	1.4	1.3	1.9	1.9	1.9	4.8	
Exports	N/A	1.7	7.5	19.9	22.4	33.8	35.5	55.6	58.4
Domestic Total On-Grid*		0.4	0.2	1.7	1.8	2.2	4.2	6.9	7.3
Domestic Total Off-Grid*		3.7	6.1	9.5	11.2	10.3	10.8	14.4	22.5
Cumulative Shipments	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total		35.2	84.7	193.3	228.8	275.2	325.7	402.5	490.7
Imports		1.0	5.6	14.3	16.2	18.0	19.9	24.7	
Exports	N/A	5.7	32.9	104.0	126.5	160.3	195.8	251.3	309.7
Domestic Total On-Grid*		2.9	4.7	8.2	9.9	12.2	16.4	23.3	30.6
Domestic Total Off-Grid*		26.6	47.2	81.1	92.4	102.7	113.5	127.9	150.4

* Domestic Totals include imports and exclude exports.

Annual U.S. Installations (MW)	Source: *The 2000 National Survey Report of Photovoltaic Power Applications in the United States, prepared by Paul D. Maycock and Ward Bower, April 30, 2001, prepared for the IEA, Table E-1.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Grid-Connected Distributed				1.5	2.0	2.0	2.2	3.7	5.5
Off-Grid Consumer				3.5	4.0	4.2	4.5	5.5	6.0
Government				0.8	1.2	1.5	1.5	2.5	2.5
Off-Grid Industrial/Commercial	N/A	N/A	N/A	4.0	4.4	4.8	5.2	6.5	7.5
Consumer (<20 w)				2.0	2.2	2.2	2.4	2.5	2.5
Central Station				0.0	0.0	0.0	0.0	0.0	0.0
Total				11.8	13.8	14.7	15.8	20.7	24.0

Cumulative U.S. Installations* (MW)	Source: *The 2000 National Survey Report of Photovoltaic Power Applications in the United States, prepared by Paul D. Maycock and Ward Bower, April 30, 2001, prepared for the IEA, Table 1.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Off-grid Residential				19.3	23.3	27.5	32.0	37.5	43.5
Off-grid Nonresidential				25.8	30.2	35.0	40.2	46.7	55.2
On-grid Distributed	N/A	N/A	N/A	9.7	11.0	13.7	15.9	21.1	28.1
On-grid Centralized				12.0	12.0	12.0	12.0	12.0	12.0
Total				66.8	76.5	88.2	100.1	117.3	138.8

* Excludes installations less than 40kW.

Annual World Installations (MW)	Source: *PV News, Vol. 19, No.11, Nov. 2000*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Consumer Products			16		22	26	30	35	40
U.S. Off-Grid Residential			3		8	9	10	13	16
World Off-Grid Rural			6		15	19	24	31	35
Communications/ Signal	N/A	N/A	14	N/A	23	28	31	35	42
PV/Diesel, Commercial			7		12	16	20	25	30
Grid-Conn Res., Commercial			1		7	27	35	60	85
Central Station (>100kW)			1		2	2	2	2	2
Total			48		89	127	152	201	250

Annual U.S. Shipments by Cell Type (MW)	Source: *PV News, Vol. 15, No. 2, Feb. 1996; Vol. 16, No. 2, Feb. 1997; Vol. 17, No. 2, Feb. 1998; Vol. 18, No. 2, Feb. 1999; Vol. 19, No. 3, March 2000; and Vol. 20, No. 3, March 2001.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Single Crystal				22.0	24.1	31.8	30.0	36.6	44.0
Flat-Plate Polycrystal (other than ribbon)				9.0	10.3	14.0	14.7	16.0	17.0
Amorphous Silicon				1.3	1.1	2.5	3.8	5.3	6.5
Crystal Silicon Concentrators				0.3	0.7	0.7	0.2	0.5	0.5
Ribbon Silicon	N/A	N/A	N/A	2.0	3.0	4.0	4.0	4.2	5.0
Cadmium Telluride				0.1	0.4	0.0	0.0	0.0	0.0
SI on Low-Cost-Sub				0.1	0.3	0.5	1.0	2.0	2.0
A-SI on Cz Slice									0.0
Total				34.8	39.9	53.5	53.7	64.6	75.0

Annual World Shipments by Cell Type (MW)

Source: *PV News, Vol. 15, No. 2, Feb. 1996; Vol. 16, No. 2, Feb. 1997; Vol. 17, No. 2, Feb. 1998; Vol. 18, No. 2, Feb. 1999; Vol. 19, No. 3, March 2000;and Vol. 20, No. 3, March 2001.*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Single Crystal				46.7	48.5	62.8	59.8	73.0	89.7
Flat-Plate Polycrystal				20.1	24.0	43.0	66.3	88.4	140.6
Amorphous Silicon				9.1	11.7	15.0	19.2	23.9	27.0
Crystal Silicon Concentrators				0.3	0.7	0.2	0.2	0.5	0.5
Ribbon Silicon	N/A	N/A	N/A	2.0	3.0	4.0	4.0	4.2	14.7
Cadmium Telluride				1.3	1.6	1.2	1.2	1.2	1.2
SI on Low-Cost-Sub				0.1	0.3	0.5	1.0	2.0	2.0
A-SI on Cz Slice								8.1	12.0
Total				79.5	89.8	126.7	151.7	201.3	287.7

Annual U.S. Shipments by Cell Type (MW)

Source: EIA, *Renewable Energy Annual 1997, Table 27, Renewable Energy Annual 2000, Table 26, and Solar Collector Manufacturing Activity annual reports, 1982-1992.*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Single-Crystal Silicon				19.9	21.7	30.0	30.8	47.2	
Cast and Ribbon Crystalline Silicon				9.9	12.3	14.3	16.4	26.2	
Crystalline Silicon Total		5.5	12.5	29.8	34.0	44.3	47.2	73.5	
Thin-Film Silicon	N/A	0.3	1.3	1.3	1.4	1.9	3.3	3.3	N/A
Concentrator Silicon				0.1	0.2	0.2	0.1	0.1	
Other									
Total		5.8	13.8	31.2	35.6	46.3	50.6	76.8	

Annual Grid-Connected Capacity (MW)

Source: *The 2000 National Survey Report of Photovoltaic Power Applications in the United States, prepared by Paul D. Maycock and Ward Bower, April 30, 2001, for the IEA, derived from Table 1; Japan data from PV News, Vol. 20, No. 7, July 2001.*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	N/A	N/A	N/A		1.3	2.7	2.2	5.2	7.0
Japan				3.9	7.5	19.5	24.1	57.7	95.8

Cumulative Grid-Connected Capacity (MW)

Source: *The 2000 National Survey Report of Photovoltaic Power Applications in the United States, prepared by Paul D. Maycock and Ward Bower, April 30, 2001, for the IEA, Table 1; Japan data from PV News, Vol. 20, No. 7, July 2001.*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	N/A	N/A	N/A	21.7	23.0	25.7	27.9	33.1	40.1
Japan				5.80	13.3	32.8	56.9	115	210

Annual U.S.-Installed Capacity (MW)

Source: *Renewable Electric Plant Information System (REPiS), Version 5, NREL, 2001.*

Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
California		0.034	0.016	0.720	0.900	0.606	0.577	2.993	3.412
Arizona		0.004		0.026	0.067	0.732	0.296	0.578	0.540
New York			0.013	0.067	0.344	0.021	0.346	0.041	0.377
Texas	0.006	0.015	0.002	0.015		0.010	0.112	0.144	0.120
Colorado				0.018	0.100	0.056	0.132	0.344	0.137
Hawaii				0.013	0.031	0.008	0.291	0.113	0.459
Georgia					0.352			0.019	0.221
Florida	0.009		0.008	0.018		0.036	0.054	0.107	0.172
Massachusetts		0.006		0.018		0.023	0.075	0.037	0.020
Washington, D.C.								0.009	0.003
Total U.S.	0.020	0.080	0.050	1.050	2.035	1.678	1.979	5.040	6.076

Cumulative U.S.-Installed Capacity (MW)

Source: *Renewable Electric Plant Information System (REPiS), Version 5, NREL, 2001.*

Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
California	0.002	1.369	2.803	6.495	7.396	8.002	8.579	11.572	14.983
Arizona	0.008	0.032	0.048	0.097	0.164	0.896	1.192	1.771	2.311
New York	0.000	0.000	0.013	0.226	0.569	0.590	0.936	0.977	1.353
Texas	0.006	0.021	0.296	0.374	0.374	0.384	0.496	0.640	0.760
Colorado	0.000	0.000	0.010	0.040	0.140	0.146	0.278	0.622	0.759
Hawaii	0.000	0.014	0.033	0.046	0.077	0.085	0.376	0.489	0.735
Georgia	0.000	0.000	0.000	0.000	0.352	0.352	0.352	0.371	0.592
Florida	0.009	0.093	0.117	0.135	0.135	0.171	0.225	0.332	0.504

Massachusetts	0.000	0.127	0.208	0.238	0.238	0.261	0.336	0.373	0.393
Washington, D.C.	0.000	0.337	0.337	0.349	0.349	0.349	0.349	0.358	0.361
Total U.S.	0.025	2.104	4.099	8.511	10.546	12.224	14.204	19.244	25.319

Technology Performance

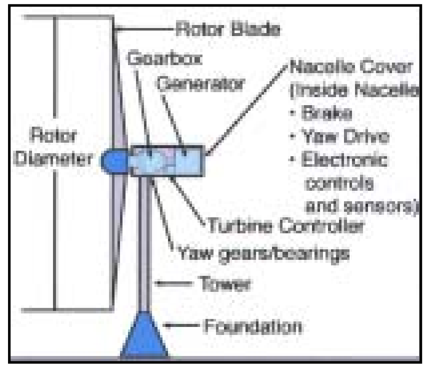
	Source: *Renewable Energy Technology Characterizations, EPRI TR-109496, 1997.C185 (Note that this document is currently being updated by DOE, and the values most likely will change).*								
Efficiency		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Cell (%)	Crystalline Silicon			24	24.7				
	Thin Film			18.0	19.0	20.0	21.0	21.5	22.0
	Concentrator			20.0	23.0	26.0	33.0	35.0	37.0
Module (%)	Crystalline Silicon			14.0	16.0	17.0	18.0	18.5	19.0
	Thin Film	N/A	N/A	10.0	12.0	15.0	17.0	17.5	18.0
	Concentrator								
System (%)	Crystalline Silicon			11.3	13.1	14.1	15.1	15.6	16.1
	Thin Film			4.8	7.2	8.8	11.2	12.0	12.8
	Concentrator			13.8	15.1	17.1	21.7	23.0	24.3
Cost		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Module ($/Wp)	Crystalline Silicon			3.8	3.0	2.3	1.8	1.4	1.1
	Thin Film			3.8	2.2	1.0	0.5	0.4	0.4
	Concentrator			1.8	1.5	0.7	0.6	0.5	0.5
BOS ($/Wp)	Crystalline Silicon			2.7	2.1	1.6	1.2	0.9	0.7
	Thin Film			3.7	2.1	1.3	0.7	0.6	0.5
	Concentrator	N/A	N/A	3.6	2.7	1.2	1.0	0.8	0.7
Total ($/Wp)	Crystalline Silicon *			6.5	5.1	3.9	3.0	2.4	1.8
	Thin Film			7.5	4.3	2.3	1.2	1.1	0.9
	Concentrator			7.6	4.0	2.0	1.6	1.3	1.1
O&M ($/kWh)	Crystalline Silicon			0.008	0.007	0.006	0.006	0.006	0.005
	Thin Film			0.023	0.008	0.003	0.002	0.002	0.001
	Concentrator			0.047	0.020	0.010	0.008	0.007	0.006

* Range in total capital cost for crystalline silicon in 2000 is $5.1/Wp to $9.1/Wp depending on market supply and demand. (Source: John Mortensen, Factors Associated with Photovoltaic System Costs, June 2001, NREL/TP 620.29649, Page 3).

Wind Energy

Technology Description

Wind-turbine technology converts the kinetic energy in the wind to mechanical energy and ultimately to electricity. Grid-connected wind power reduces GHG emissions by displacing the need for natural gas- and coal-fired generation. Village and off-grid applications are important for displacing diesel generation and for improving quality of life, especially overseas.



System Concepts

- The principle of wind energy conversion is simple: Wind passing over the blade creates lift, producing a torque on the rotor shaft that turns a gearbox. The gearbox is coupled to an electric generator that produces power at the frequency of the host power system. Some new innovative designs use low-speed generators, which eliminate the need for a gearbox.

Representative Technologies

- Two major design approaches are being used: (1) typical of historic European technology—three-bladed, up-wind, stiff, heavy machines that resist cyclic and extreme loads, and (2) lightweight, flexible machines that bend and absorb loads, primarily being developed by U.S. designers. Several alternative configurations within each approach are being pursued.

Technology Applications

- Thirty-seven states have land area with good winds (13 mph annual average at 10 m height, wind Class 4, or better).
- For wind-farm or wholesale power applications, the principal competition is natural gas for new construction and natural gas in existing units for fuel saving. Utility restructuring is a critical challenge to increased deployment in the near-term because it emphasizes short-term, low capital-cost alternatives and lacks public policy to support deployment of sustainable technologies such as wind energy.

Current Status

- Wind technology is competitive today in bulk power markets with support from the production tax credit, and in high-value niche applications or markets that recognize noncost attributes.
- Current performance is characterized by levelized costs of 4 to 5.5¢/kWh (depending on resource intensity and financing structure), capacity factors of 30 to 40 percent, availability of 95 to 98%, total installed project costs ("overnight" – not including construction financing) of $800 to $1,100/kW, and efficiencies of 65% to 75% of the theoretical (Betz limit) maximum.
- The worldwide annual market growth rate for wind technology is at a level of 30% with new markets opening in many developing countries. Domestic public interest in environmentally responsible electric generation technology is reflected by new state energy policies and in the success of "green marketing" of wind power across the country.
- Preliminary estimates are that installed capacity at the end of 2001 was 4,260 MW in the United States, and 23,300 MW worldwide; compared to 2,550 MW in the United States and 17,653 worldwide in 2000; and 2,450 MW in the United States and 13,598 MW worldwide in 1999.
- U.S. energy generation from wind was nearly 5 TWh out of a worldwide total of 30 TWh in 2000, up from 4.5 TWh out of an approximate total of 26 TWh in 1999.
- Twelve states had more than 20 MW of large wind-turbine capacity at the end of 2001, with 15 additional states having less than 20 MW each.
- In the United States, the wind industry is thinly capitalized, except for the acquisition of Enron

Wind Corporation by General Electric Co. About six manufacturers and six to 10 developers characterize the U.S. industry.

- Enron Wind Corporation is being acquired by General Electric Corporation, Power Turbine Division.
- In Europe, there are about 12 turbine manufacturers and about 20 to 30 project developers. European manufacturers have established North American manufacturing facilities and are actively participating in the U.S. market.
- Current leading wind companies and sales volume are shown below:

	U.S. Market (2001) (Estimated)		**World Market (2000)**	
	MW	Percent	MW	Percent
Vestas (DK	652	38.6	805	17.9
Enron/GE (USA)	395	23.3	270	6.0
Bonus (DK)	278	16.4	516	11.5
Mitsubishi (JP)	221	13.1	64	1.4
NEG Micon (DK)	115	6.8	601	13.4
Nordex (DK)	2.6	-	375	8.3
Enercon (D)	-	-	617	13.7
Gamesa (SP)	-	-	623	13.9
Ecotecnia (SP)	-	-	174	3.9
Suzlon (Ind)	-	-	103	2.3
Dewind (GE)	-	-	94	2.1
MADE (SP)	-	-	85	1.9
Others			165	3.7

Sources: U.S. Market – NREL, November 2001, World Market – BTM Consult, ApS, "World Market Update 2000"

Technology History

- Prior to 1980, DOE sponsored, and NASA managed, large-scale turbine development – starting with hundred-kilowatt machines and culminating in the late 1980s with the 3.2-MW, DOE-supported Mod-5 machine built by Boeing.
- Small-scale (2-20 kW) turbine development efforts also were supported by DOE at the Rocky Flats test site. Numerous designs were available commercially for residential and farm uses.
- In 1981, the first wind farms were installed in California by a small group of entrepreneurial companies. PURPA provide substantial regulatory support for this initial surge.
- During the next five years, the market boomed, installing U.S., Danish, and Dutch turbines.
- By 1985, annual market growth had peaked at 400 MW. Following that, federal tax credits were abruptly ended, and California incentives weakened the following year.
- In 1988, European market exceeded the U.S. for the first time, spurred by ambitious national programs. A number of new companies emerged in the U.K. and Germany.
- In 1989, DOE's focus changed to supporting industry-driven research on components and systems. At the same time, many U.S. companies became proficient in operating the 1600 MW of installed Capacity in California. They launched into value engineering and incremental increases in turbine size.
- DOE program supported value-engineering efforts and other advanced turbine-development efforts.
- In 1992, Congress passed the Renewable Energy Production Tax Credit (REPI), which provided a 1.5 cent/kWh tax credit for wind-produced electricity. Coupled with several state programs and mandates, installations in the United States began to increase.
- In 1997, Enron purchased Zond Energy Systems, one of the value-engineered turbine manufacturers. In 2002, General Electric Co. purchased Enron Wind Corporation.
- In FY2001, DOE initiated a low wind-speed turbine development program to broaden the U.S. cost-competitive resource base.

Technology Future

The levelized cost of electricity for wind energy technology is projected to be:

	2000	2002	2010	2020
Class 4	6.0	5.5	3.0	2.7
Class 6	4.2	4.0	2.4	2.2

Assumptions include: 30-year levelized cost, constant January 2002 dollars, generation company ownership/financial assumptions; wind plant comprised of 100 turbines; no financial incentives included.
Source: FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001

- Wind energy's competitiveness by 2005 will be affected by policies regarding ancillary services and transmission and distribution regulations. Substantial cost reductions are expected for wind turbines designed to operate economically in low wind-speed sites, which will increase the amount of economical wind resource areas by 20-fold, and will be within 100 miles of most load centers.
- Initial lower levels of wind deployment (up to 15–20% of the total U.S. electric system capacity) are not expected to introduce significant grid reliability issues. Inasmuch as the wind blows only intermittently, intensive use of this technology at larger penetrations may require modification to system operations or ancillary services. Transmission infrastructure upgrades and expansion will be required for large penetrations of wind energy to service major load centers.
- Over the long-term, as more high wind sites become used, emphasis will shift toward installation in lower wind-speed sites. Advances in technology will include various combinations of the following improvements, accomplished through continuing R&D:

*Tower*s – taller for more energy, softer to shed loads, advanced materials, and erection techniques to save cost

Rotors – Improving airfoils and plan forms to increase energy capture. For instance, a variable rotor diameter; larger rotors at the same cost or small cost increase by optimizing design and manufacturing, using lighter materials, and implementing controls to mitigate loads.

Drive Train and Generators – New designs to reduce weight and cost. Advances in power electronics and operational algorithms to optimize drive-train efficiencies, especially by increasing low efficiencies in ranges of operation that are currently much lower than those in the peak range. In addition to new power electronics and operational approaches, possible advances include permanent magnet generators, and use of single-stage transmissions coupled with multiple smaller, simpler, off-the-shelf generators that can be purchased from high-volume manufacturers.

Controls – By reducing loads felt throughout the turbine, various approaches for passive and active control of turbines will enable larger, taller structures to be built for comparatively small cost increases, resulting in improvements in system cost of energy.

Design Codes – Reductions in design margins also will decrease the cost of turbines and allow for larger turbines to be built for comparatively small increases in cost, resulting in improvements in system cost of energy.

Foundations – New designs to lower cost.

Utility Grid Integration – Models and tools to analyze the steady and dynamic impact and operational characteristics of large wind farms on the electric grid will facilitate wind power integration. Improved wind forecasting and development of various enabling technologies will increase the value of wind power.

Wind

Market Data

Grid-Connected Wind Capacity		*Source: Reference IEA (data supplemented by Windpower Monthly, April 2001, and 2001 data from Windpower Monthly, January 2002).*									
Cumulative (MW)		**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
	U.S.	10	1,039	1,525	1,770	1,794	1,741	1,890	2,455	2,554	4,240
	Denmark	3	50	310	630	785	1,100	1,400	1,752	2,338	2,417
	Netherlands	0	0	49	255	305	325	364	416	447	483
	Germany	2	3	60	1,137	1,576	2,082	2,874	4,445	6,095	8,100
	Spain	0	0	9	126	216	421	834	1,539	2,334	3,175
	UK	0	0	6	193	264	324	331	344	391	477
	Europe	5	58	450	2,494	3,384	4,644	6,420	9,399	12,961	16,362
	India	0	0	20	550	820	933	968	1,095	1,220	1,426
	Japan	0	0	1	10	14	7	32	75	121	250
	Rest of World	0	0	6	63	106	254	315	574	797	992
	World Total	15	1,097	2,002	4,887	6,118	7,579	9,625	13,598	17,653	23,270
		Source: Renewable Energy Project Information System (REPiS), Version 5, NREL, 2001.									
Annual (MW)		**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
	U.S.	0.0	336.6	153.7	42.7	1.4	7.6	186.1	657.7		
Cumulative (MW)											
	U.S.	0.1	674	1,569	1,778	1,779	1,787	1,973	2,631		

Annual Market Shares

Source: US DOE- 1982-87 wind turbine shipment database; 1988-94 DOE Wind Program Data Sheets; 1996-2000 American Wind Energy Association

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S. Mfg Share of U.S. Market	98%	44%	36%	67%	NA	38%	78%	44%	0%
U.S. Mfg Share of World Market	65%	42%	20%	5%	2%	4%	13%	9%	6%

State-Installed Capacity

Source: *American Wind Energy Association.*

Annual State-Installed Capacity (MW)

Top 10 States	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001
California*		N/A	N/A	3.0	0.0	8.4	0.7	250.0	0.0	67.1
Texas		0.0	0.0	41.0	0.0	0.0	0.0	139.2	0.0	915.2
Iowa		0.0	0.0	0.1	0.0	1.2	3.1	237.5	0.0	81.8
Minnesota		0.0	0.0	0.0	0.0	0.2	109.2	137.6	17.8	28.6
Washington		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	178.2
Oregon		0.0	0.0	0.0	0.0	0.0	25.1	0.0	0.0	132.4
Wyoming		0.0	0.0	0.0	0.1	0.0	1.2	71.3	18.1	50.0
Kansas		0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	112.2
Colorado		0.0	0.0	0.0	0.0	0.0	0.0	21.6	0.0	39.6
Wisconsin		0.0	0.0	0.0	0.0	0.0	1.2	21.8	0.0	30.0
Total of 10 States		N/A	N/A	44.1	0.1	10	141	881	36	1,635
Total U.S.		N/A	N/A	44	1	16	142	884	67	1,694

Cumulative State-Installed Capacity (MW)

Top 10 States (as of 2001)	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001
California*		N/A	N/A	1,387	1,387	1,396	1,396	1,646	1,646	1,714
Texas		0.0	0.0	41.0	41.0	41.0	41.0	180.2	180.2	1,096
Iowa		0.0	0.0	0.7	0.8	2.0	5.0	242.5	242.5	324.2
Minnesota		0.0	0.0	25.7	25.7	25.9	135.1	272.7	290.5	319.1
Washington		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	178.2
Oregon		0.0	0.0	0.0	0.0	0.0	25.1	25.1	25.1	157.5
Wyoming		0.0	0.0	0.0	0.1	0.1	1.3	72.5	90.6	140.6
Kansas		0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5	113.7
Colorado		0.0	0.0	0.0	0.0	0.0	0.0	21.6	21.6	61.2

Wisconsin	0.0	0.0	0.0	0.0	0.0	1.2	23.0	23.0	53.0
Total of 10 States	N/A	N/A	1,455	1,455	1,465	1,605	2,486	2,521	4,157
Total U.S.	N/A	N/A	1,457	1,457	1,474	1,616	2,500	2,566	4,261

* The data set includes 1,193.53 MW of wind in California that is not given a specific installation year, but rather a range of years (1072.36 MW in 1981-1995, 87.98 in 1982-1987, and 33.19 MW in "mid-1980's"), this has led to the "Not Available" values for 1985 and 1990 for California and the totals, and this data is not listed in the annual installations, but has been added to the cumulative totals for 1995 and on.

Annual Generation from Cumulative Installed Capacity (Billion kWh)

Source: U.S. - *EIA, Monthly Energy Review, December 2001- Table 7.2; IEA Countries - IEA Wind Energy Annual Reports, 1995-2000.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S.			3.0	3.2	3.4	3.2	3.0	4.5	5.0
IEA Countries				7.5	8.5	11.0	12.0	22.0	26.0

Technology Performance

Energy Production

Source: *U.S.DOE Wind Program, 1980-1995, FY03 U.S.DOE Wind Program Internal Planning Documents, Summer 2001, 2000-2020*

		1980	1985	1990	1995	2000	2005	2010	2015	2020
Capacity Factor (%)	Class 4		10	15	20	25.2	32.6	44.7	46.5	47.1
	Class 6		20	22	25	39.4	44.3	49.6	50.9	53.8
Specific Energy (kWh/m^2*)	Class 4		500	800	850	900	1,110	1,260	1,310	1,330
	Class 6		900	1,150	1,300	1,400	1,650	1,700	1,740	1,760
Production Efficiency** (kWh/kW)	Class 4	200	650	1,300	1,750	2,200	2,860	3,500	3,600	3,600
	Class 6	800	1,700	1,900	2,200	3,450	3,880	4,350	4,450	4,700

* m^2 is the rotor swept area.

** Production Efficiency is the net energy per unit of installed capacity.

Cost*			1980	1985	1990	1995	2000	2005	2010	2015	2020
	Source: *FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001.*										
	Project Cost ($/kW)	Class 4					1,000	915	910	880	860
	(Overnight costs)	Class 6					1,000	900	800	770	750
	O&M ($/kW)	Class 4					11.0	7.9	7.0	6.9	6.6
		Class 6					17.3	8.0	7.8	7.6	7.5
	Fixed O&M & Land	Class 4					8.0	8.0	8.0	8.0	8.0
	($/kW)	Class 6					8.0	8.0	8.0	8.0	8.0

Specific Cost* (Project Capital Cost Per Rotor Captured Area - $/m2)		1980	1985	1990	1995	2000	2005	2010	2015	2020
Source: FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001, 2000-2020.										
	Class 4					382	357	293	283	277
	Class 6					414	340	312	300	276

* Jan. 2002 dollars

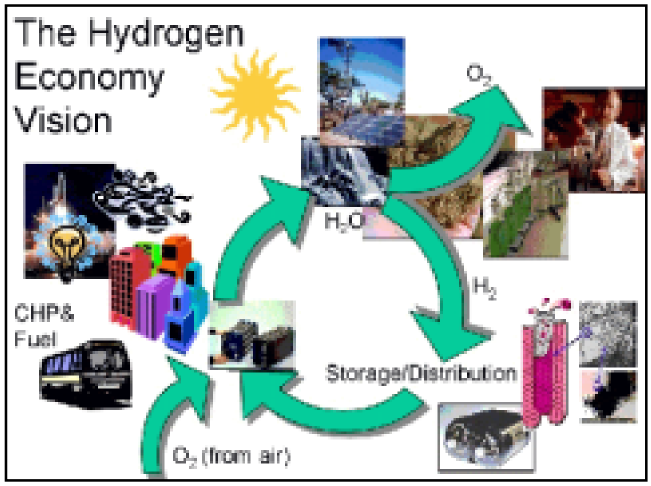
Levelized Cost of Energy* ($/kWh)		1980	1985	1990	1995	2000	2005	2010	2015	2020
Source: *U.S. DOE Wind Program 1980-1985; FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001, 2000-2020*										
	Class 4			0.12	0.080	0.060	0.041	0.030	0.028	0.027
	Class 6			0.08	0.060	0.042	0.027	0.024	0.023	0.022

* 30-year term, constant January 2002 dollars. Generation Company Ownership/Financial Assumptions. Wind plant comprised of 100 turbines. No financial incentives are included.

Hydrogen

Technology Description

Like electricity, hydrogen can be produced from many sources, including fossil fuels, renewable resources, and nuclear energy. Hydrogen and electricity can be converted from one to the other using electrolyzers (electricity to hydrogen) and fuel cells (hydrogen to electricity). Hydrogen is an effective energy storage medium, particularly for distributed generation. When hydrogen produced from renewable resources is used in fuel cell vehicles or power devices, there are very few emissions—the major byproduct is water. With improved conventional energy conversion and carbon-capture technologies, hydrogen from fossil resources can be used efficiently with few emissions.



The Hydrogen Economy vision is based on a clean and elegant cycle: separate water into hydrogen and oxygen using renewable or nuclear energy, or fossil resources with carbon sequestration. Use the hydrogen to power a fuel cell, internal combustion engine, or turbine, where hydrogen and oxygen (from air) recombine to produce electrical energy, heat, and water to complete the cycle. This process produces no particulates, no carbon dioxide, and no pollution.

System Concepts

- Hydrogen made via electrolysis from excess nuclear or renewable energy can be used as a sustainable transportation fuel or stored to meet peak-power demand. It also can be used as a feedstock in chemical processes.
- Hydrogen produced by decarbonization of fossil fuels followed by sequestration of the carbon can enable the continued, clean use of fossil fuels during the transition to a carbon-free Hydrogen Economy.
- A hydrogen system is comprised of production, storage, distribution, and use.
- A fuel cell works like a battery but does not run down or need recharging. It will produce electricity and heat as long as fuel (hydrogen) is supplied. A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. Hydrogen is fed to the anode, and oxygen is fed to the cathode. Activated by a catalyst, hydrogen atoms separate into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they reunite with oxygen and the electrons to produce water and heat. Fuel cells can be used to power vehicles, or to provide electricity and heat to buildings.

Representative Technologies

Hydrogen production

- Thermochemical conversion of fossil fuels, biomass, and wastes to produce hydrogen and CO_2 with the CO_2 available for sequestration (large-scale steam methane reforming is widely commercialized)
- Renewable (wind, solar, geothermal, hydro) and nuclear electricity converted to hydrogen by electrolysis of water (commercially available electrolyzers supply a small but important part of the super-high-purity hydrogen market)
- Photoelectrochemical and photobiological processes for direct production of hydrogen from sunlight and water.

Hydrogen storage
- Pressurized gas and cryogenic liquid (commercial today)
- Higher pressure (10,000 psi), carbon-wrapped conformable gas cylinders
- Cryogenic gas
- Chemically bound as metal or chemical hydrides or physically adsorbed on carbon nanostructures

Hydrogen distribution
- By pipeline (relatively significant pipeline networks exist in industrial areas of the Gulf Coast region, and near Chicago)
- By decentralized or point-of-use production using natural gas or electricity
- By truck (liquid and compressed hydrogen delivery is practiced commercially)

Hydrogen use
- Transportation sector: internal combustion engines or fuel cells to power vehicles with electric power trains. Potential long-term use as an aviation fuel and in marine applications
- Industrial sector: ammonia production, reductant in metal production, hydrotreating of crude oils, hydrogenation of oils in the food industry, reducing agent in electronics industry, etc.
- Buildings sector: combined heat, power, and fuel applications using fuel cells
- Power sector: fuel cells, gas turbines, generators for distributed power generation

Technology Applications

- In the United States, nearly all of the hydrogen used as a chemical (i.e. for petroleum refining and upgrading, ammonia production) is produced from natural gas. The current main use of hydrogen as a fuel is by NASA to propel rockets.
- Hydrogen's potential use in fuel and energy applications includes powering vehicles, running turbines or fuel cells to produce electricity, and generating heat and electricity for buildings. The current focus is on hydrogen's use in fuel cells.

The primary fuel cell technologies under development are:

Phosphoric acid fuel cell (PAFC) - A phosphoric acid fuel cell (PAFC) consists of an anode and a cathode made of a finely dispersed platinum catalyst on carbon paper, and a silicon carbide matrix that holds the phosphoric acid electrolyte. This is the most commercially developed type of fuel cell and is being used in hotels, hospitals, and office buildings. The phosphoric acid fuel cell also can be used in large vehicles, such as buses.

Proton-exchange membrane (PEM) - The proton-exchange membrane (PEM) fuel cell uses a fluorocarbon ion exchange with a polymeric membrane as the electrolyte. The PEM cell appears to be more adaptable to automobile use than the PAFC type of cell. These cells operate at relatively low temperatures and can vary their output to meet shifting power demands. These cells are the best candidates for light-duty vehicles, for buildings, and much smaller applications.

Solid oxide fuel cells (SOFC) - Solid oxide fuel cells (SOFC) currently under development use a thin layer of zirconium oxide as a solid ceramic electrolyte, and include a lanthanum manganate cathode and a nickel-zirconia anode. This is a promising option for high-powered applications, such as industrial uses or central electricity generating stations.

Direct-methanol fuel cell (DMFC) - A relatively new member of the fuel cell family, the direct-methanol fuel cell (DMFC) is similar to the PEM cell in that it uses a polymer membrane as an electrolyte. However, a catalyst on the DMFC anode draws hydrogen from liquid methanol, eliminating the need for a fuel reformer.

Molten carbonate fuel cell (MCFC) - The molten carbonate fuel cell uses a molten carbonate salt as the electrolyte. It has the potential to be fueled with coal-derived fuel gases or natural gas.

Alkaline fuel cell - The alkaline fuel cell uses an alkaline electrolyte such as potassium hydroxide. Originally used by NASA on missions, it is now finding applications in hydrogen-powered vehicles.

Regenerative or Reversible Fuel Cells - This special class of fuel cells produces electricity from hydrogen and oxygen, but can be reversed and powered with electricity to produce hydrogen and oxygen.

Current Status

• Currently, 48% of the worldwide production of hydrogen is via large-scale steam reforming of natural gas. Today, we safely use about 90 billion cubic meters (3.2 trillion cubic feet) of hydrogen yearly.

• Direct conversion of sunlight to hydrogen using a semiconductor-based photoelectrochemical cell was recently demonstrated at 12.4% efficiency.

• Hydrogen technologies are in various stages of development across the system:

Production - Hydrogen production from conventional fossil-fuel feedstocks is commercial, and results in significant CO2 emissions. Large-scale CO2 sequestration options have not been proved and require R&D. Current commercial electrolyzers are 80-85% efficient, but the cost of hydrogen is strongly dependent on the cost of electricity. Production processes using wastes and biomass are under development, with a number of engineering scale-up projects underway.

Storage - Liquid and compressed gas tanks are available and have been demonstrated in a small number of bus and automobile demonstration projects. Lightweight, fiber-wrapped tanks have been developed and tested for higher-pressure hydrogen storage. Experimental metal hydride tanks have been used in automobile demonstrations. Alternative solid-state storage systems using alanates and carbon nanotubes are under development.

Use - Small demonstrations by domestic and foreign auto and bus companies have been undertaken. Small-scale power systems using fuel cells are being beta-tested. Small fuel cells for battery replacement applications have been developed. Much work remains.

• Recently, there have been important advances in storage energy densities in recent years: high pressure composite tanks have been demonstrated with 7.5 wt.% storage capacity, exceeding the current DOE target, and new chemical hydrides have demonstrated a reversible capacity of 5 wt.% hydrogen. The composite tank development is a successful technology partnership among the national labs, DOE, and industry. Industrial investment in chemical hydride development recently has been initiated.

• SunLine Transit receives support to operate a variety of hydrogen production processes for its bus fleet. The California Fuel Cell Partnership has installed hydrogen refueling equipment (liquid delivered to the facility)

• Major industrial companies are pursuing R&D in fuel cells and hydrogen reformation technologies with a mid-term timeframe for deployment of these technologies for both stationary and vehicular applications. These companies include:

ExxonMobil	Toyota
Shell	Daimler-Chrysler
Texaco	Honda
BP	International Fuel Cells
General Motors	Ballard
Ford	Air Products
Daimler-Chrysler	Praxair
Toyota	Plug Power Systems

Technology History

• From the early 1800s to the mid-1900s, a gaseous product called town gas (manufactured from coal) supplied lighting and heating for America and Europe. Town gas is 50% hydrogen, with the rest comprised of mostly methane and carbon dioxide, with 3% to 6% carbon monoxide. Then, large natural gas fields were discovered, and networks of natural gas pipelines displaced town gas. (Town gas is still found in limited use today in Europe and Asia.)

• From 1958 to present, the National Aeronautics and Space Administration (NASA) has continued work on using hydrogen as a rocket fuel and electricity source via fuel cells. NASA became the worldwide largest user of liquid hydrogen and is renowned for its safe handling of hydrogen.

• During the 20th century, hydrogen was used extensively as a key component in the manufacture of ammonia, methanol, gasoline, and heating oil. It was—and still is—also used to make fertilizers, glass, refined metals, vitamins, cosmetics, semiconductor circuits, soaps, lubricants, cleaners, margarine, and peanut butter.

• Recently, (in the late 20th century/dawn of 21st century) many industries worldwide have begun producing hydrogen, hydrogen-powered vehicles, hydrogen fuel cells, and other hydrogen products. From Japan's hydrogen delivery trucks to BMW's liquid-hydrogen passenger cars, to Ballard's fuel cell transit buses in Chicago and Vancouver, B.C.; to Palm Desert's Renewable Transportation Project, to Iceland's commitment to be the first hydrogen economy by 2030; to the forward-thinking work of many hydrogen organizations worldwide, to Hydrogen Now!'s public education work; the dynamic progress in Germany, Europe, Japan, Canada, the United States, Australia, Iceland, and several other countries launch hydrogen onto the main stage of the world's energy scene.

Technology Future

• Fuel cells are a promising technology for use as a source of heat and electricity for buildings, and as an electrical power source for electric vehicles. Although these applications would ideally run off pure hydrogen, in the near-term they are likely to be fueled with natural gas, methanol, or even gasoline. Reforming these fuels to create hydrogen will allow the use of much of our current energy infrastructure—gas stations, natural gas pipelines, etc.—while fuel cells are phased in. The electricity grid and the natural gas pipeline system will serve to supply primary energy to hydrogen producers.

• By 2005, if DOE R&D goals are met, (1) onboard hydrogen storage in metal hydrides at >5 wt% will be developed; (2) complete engineering design of a small-scale, mass-producible reformer for natural gas will be completed; and (3) an integrated biomass-to-hydrogen system will be demonstrated.

• By 2010, advances will be made in photobiological and photoelectrochemical processes for hydrogen production, efficiencies of fuel cells for electric power generation will increase, and advances will be made in fuel cell systems based on carbon structures, alanates, and metal hydrides

• Although comparatively little hydrogen is currently used as fuel or as an energy carrier, the long-term potential is for us to make a transition to a hydrogen-based economy in which hydrogen will join electricity as a major energy carrier. Furthermore, much of the hydrogen will be derived from domestically plentiful renewable energy or fossil resources, making the Hydrogen Economy synonymous with sustainable development and energy security.

• In summary, future fuel cell technology will be characterized by reduced costs and increased reliability for transportation and stationary (power) applications

• For a fully developed hydrogen energy system, a new hydrogen infrastructure/delivery system will be required.

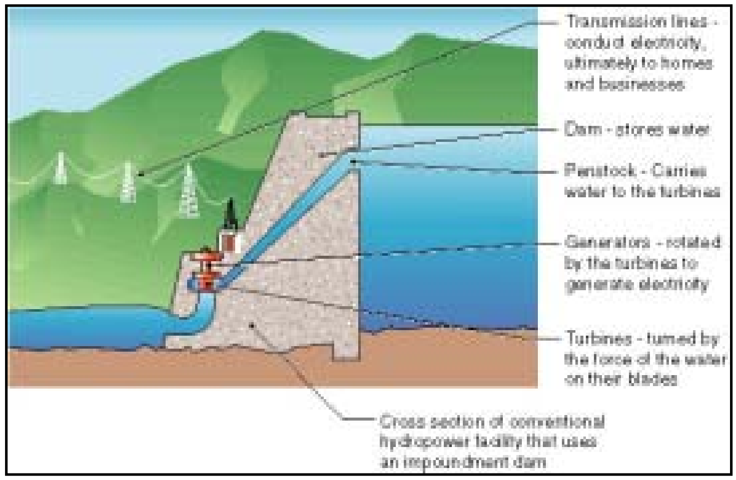
• In the future, hydrogen also could join electricity as an important *energy carrier*. An energy carrier stores, moves, and delivers energy in a usable form to consumers. Renewable energy sources, like the sun or wind, can't produce energy all the time. The sun doesn't always shine nor the wind blow. But hydrogen can store this energy until it is needed and it can be transported to where it is needed.

• Some experts think that hydrogen will form the basic energy infrastructure that will power future societies, replacing today's natural gas, oil, coal, and electricity infrastructures. They see a new *hydrogen economy* to replace our current energy economies, although that vision probably won't happen until far in the future.

Advanced Hydropower

Technology Description

Advanced hydropower is new technology for producing hydroelectricity more efficiently, with improved environmental performance. Current technology often has adverse environmental effects, such as fish mortality and changes to downstream water quality and quantity. The goal of advanced hydropower technology is to maximize the use of water for hydroelectric generation while eliminating these adverse side effects—in many cases both increased energy and improved environmental conditions can be achieved.



System Concepts

- Conventional hydropower projects use either impulse or reaction turbines to convert kinetic energy in flowing or falling water into turbine torque and power. Source water may be from free-flowing rivers/streams/canals or released from upstream storage reservoirs.
- Improvements and efficiency measures can be made in dam structures, turbines, generators, substations, transmission lines, and systems operation that will help sustain hydropower's role as a clean, renewable energy source.

Representative Technologies

- Turbine designs that minimize entrainment mortality of fish during passage through the power plant.
- Autoventing turbines to increase dissolved oxygen in discharges downstream of dams.
- Reregulating and aerating weirs used to stabilize tailwater discharges and improve water quality.
- Adjustable-speed generators producing hydroelectricity over a wider range of heads and providing more uniform instream flow releases without sacrificing generation opportunities.
- New assessment methods to balance instream flow needs of fish with water for energy production.
- Advanced instrumentation and control systems that modify turbine operation to maximize environmental benefits and energy production.

Technology Applications

- Advanced hydropower products can be applied at more than 80% of existing hydropower projects (installed conventional capacity is now 78 GW); the potential market also includes 15–20 GW at existing dams without hydropower facilities (i.e., no new dams required for development) and about 30 GW at undeveloped sites that have been identified as suitable for new dams.
- The nation's largest hydropower plant is the 7,600 megawatt Grand Coulee power station on the Columbia River in Washington State. The plant is being upscaled to 10,080 megawatts, which will place it second in the world behind a colossal 13,320 megawatt plant in Brazil.
- There would be significant environmental benefits from installing advanced hydropower technology, including enhancement of fish stocks, tailwater ecosystems, and recreational opportunities. These benefits would occur because the advanced technology reverses adverse effects of the past.
- Additional benefits would come from the protection of a wide range of ancillary benefits that are provided at hydropower projects but are at extreme risk of becoming lost in the new deregulated environment.

Current Status

- Hydropower (also called hydroelectric power) facilities in the United States can generate enough power to supply 28 million households with electricity, the equivalent of nearly 500 million barrels of oil. The total U.S. hydropower capacity—including pumped storage facilities—is about 95,000 megawatts. Researchers are working on advanced turbine technologies that will not only help maximize the use of hydropower but also minimize adverse environmental effects.
- According to EIA, hydropower provided 12.6% of the nation's electricity generating capability in 1999 and 80% of the electricity produced from renewable energy sources.
- DOE estimates current capital costs for large hydropower plants to be $1,700 to $2,300 per kW (although no new plants are currently being built in the United States and O&M is estimated at approximately 0.7 cents/kWh).
- Worldwide, hydropower plants have a combined capacity of 675,000 megawatts and annually produce more than 2.3 trillion kilowatt-hours of electricity, the energy equivalent of 3.6 billion barrels of oil.
- Existing hydropower generation is declining because of a combination of real and perceived environmental problems, regulatory pressures, and changes in energy economics (deregulation, etc.); potential hydropower resources are not being developed for similar reasons.
- The current trend is to replace hydropower with electricity from fossil fuels.
- Some new, environmentally friendly technologies are being implemented (e.g., National Hydropower Association's awards for Outstanding Stewardship of America's Rivers).
- DOE's Advanced Hydropower Turbine System (AHTS) program is also demonstrating that new turbine designs are feasible, but additional support is needed to fully evaluate these new designs in full-scale applications.
- There is insufficient understanding of how fish respond to turbulent flows in draft tubes and tailraces to support biological design criteria for those zones of power plants.
- Fish resource management agencies do not recognize that the route through turbines is acceptable for fish – this perception could be overcome if field-testing continues to show mortality through turbines is not greater than other passage routes.
- TVA's Lake Improvement Plan has demonstrated that improved turbine designs can be implemented with significant economic and environmental benefits.
- Field-testing of the Minimum Gap Runner (MGR) designs for Kaplan turbines indicate that fish survival up to 98% is possible, if conventional turbines are modified.
- FERC instituted a short-term reduction in regulatory barriers on the West Coast in 2001—this resulted in more than 100,000 MWh of additional generation and a significant shift from nonpeak to peak production, without significant adverse environmental effects.
- Regulatory trends in relicensing are to shift operation from peaking to baseload, effectively reducing the energy value of hydroelectricity; higher instream flow requirements are also reducing total energy production to protect downstream ecosystems, but scientific justification is weak.
- Frequent calls for dam removal is making relicensing more costly to dam owners.
- Regional efforts by Army Corps of Engineers and Bonneville Power Administration are producing some site-specific new understanding, especially in the Columbia River basin, but commercial applications are unlikely because of pressures from industry deregulation and environmental regulation.
- Voith-Siemans Hydro and TVA have established a limited partnership to market environmentally friendly technology at hydropower facilities. Their products were developed in part by funding provided by DOE and the Corps of Engineers, as well as private sources.
- Flash Technology is developing strobe lighting systems to force fish away from hydropower intakes and to avoid entrainment mortality in turbines.

Technology History

- Since the time of ancient Egypt, people have used the energy in flowing water to operate machinery and grind grain and corn. However, hydropower had a greater influence on people's lives during the 20th century than at any other time in history. Hydropower played a major role in making the wonders of electricity a part of everyday life and helped spur industrial development. Hydropower continues to produce 24% of the world's electricity and supply more than 1 billion people with power.
- The first hydroelectric power plant was built in 1882 in Appleton, Wisconsin, to provide 12.5 kilowatts to light two paper mills and a home. Today's hydropower plants generally range in size from several hundred kilowatts to several hundred megawatts, but a few mammoth plants have capacities up to 10,000 megawatts and supply electricity to millions of people.
- By 1920, 25% of electrical generation in the United States was from hydropower; and, by 1940, was 40%.
- Most hydropower plants are built through federal or local agencies as part of a multipurpose project. In addition to generating electricity, dams and reservoirs provide flood control, water supply, irrigation, transportation, recreation, and refuges for fish and birds. Private utilities also build hydropower plants, although not as many as government agencies.

Technology Future

- By 2003, a quantitative understanding of the responses of fish to multiple stresses inside a turbine should be developed. Biological performance criteria for use in advanced turbine design also should be available.
- By 2005, environmental mitigation studies should be available on topics such as in-stream flow needs to produce more efficient and less controversial regulatory compliance. In addition, pilot-scale testing of new runner designs, including field evaluation of environmental performance, will allow full-scale prototype construction and testing to proceed.
- By 2010, full-scale prototype testing of AHTS designs should be completed, including verified biological performance of AHTS in the field. This will allow AHTS technology to be transferred to the market.

Hydroelectric Power

Market Data

Cumulative Grid-Connected Hydro Capacity (MW)*	Source: U.S. data from *EIA, AEO 1998-2002- Tables A9 and A17, Renewable Resources in the Electric Supply, 1993- Table 4. World Total from EIA, International Energy Annual, 1996-1999, Table 6.4. International data from International Energy Agency, Electricity Information 1997 (1998 edition).*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.									
Conventional and other Hydro			72,900	78,480	78,390	78,530	79,110	80,280	80,270
Pumped Storage				19,900	19,600	19,600	19,300	19,200	19,200
U.S. Hydro Total				98,380	97,990	98,130	98,410	99,480	99,470
OECD Europe	119,650	126,500	132,270	134,190	134,440				
IEA Europe	118,450	125,100	130,740	131,730	132,000				
Japan	18,280	19,980	20,820	21,160	21,210				
OECD Total	278,310	309,220	324,530	321,520	321,380				
IEA Total	271,060	301,210	315,130	308,160	307,420				
World Total					656,000	667,000	678,000	683,000	

*excludes pumped storage, except for specific U.S. pumped storage capacity listed.

Annual Generation from Cumulative Installed Capacity (Billion kWh)	Source: EIA, International Energy Annual 1999, DOE/EIA-0219(99), Table 1.5.								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
United States	300	325	298	334	376	376	339	324	
Canada	251	301	294	332	352	347	329	340	
Mexico	17	26	23	27	31	26	24	32	
Japan	88	82	88	81	80	89	92	85	
Western Europe	393	417	411	447	423	440	454	466	
Former Soviet Union	184	205	231	238	215	216	224	226	

Eastern Europe	55	50	43	56	60	58	61	59	
China	58	91	125	184	185	193	203	223	
Brazil	128	177	205	251	263	276	288	306	
Rest of World	284	341	459	550	559	571	573	565	
World Total	1,758	2,015	2,176	2,501	2,543	2,594	2,587	2,626	

State Generating Capability (MW) Source: *EIA, Electric Power Annual Vol.1: 1994 & 1999-2000- Table 2, 1995-1997- Table 5.*

Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Washington				21,054	21,038	21,054			
Oregon				9,021	9,031	9,038			
California				13,504	13,538	13,535			
New York				7,246	7,311	5,279			
Montana				2,514	2,551	2,546			
Idaho				2,416	2,418	2,432			
Arizona				2,833	2,884	2,884			
Alabama				2,959	2,962	2,881			
South Dakota				1,820	1,820	1,820			
Tennessee				3,668	3,744	3,725			
U.S. Total			90,885	96,629	96,342	94,477	98,471	99,041	99,068

State Annual Generation from Cumulative Installed Capacity* (Billion kWh) Source: *EIA, Electric Power Annual Vol. 1: 1998-2000- Table A12, 1996-1997- Table 10.*

Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Washington				82.0	98.1	103.6	79.8	97.0	80.5
Oregon				40.4	44.5	46.3	39.9	45.6	38.2
California				47.4	44.1	39.8	50.8	40.4	39.2
New York				23.6	26.0	27.9	28.2	23.6	24.2
Montana				10.7	13.7	13.3	11.1	13.8	12.1
Idaho				10.1	12.2	13.5	12.9	13.4	11.0
Arizona				8.5	9.5	12.4	11.2	10.1	8.6
Alabama				9.5	11.1	11.5	10.6	7.8	5.8

South Dakota	6.0	8.0	9.0	5.8	6.7	5.7
Tennessee	8.2	9.9	9.4	10.2	7.2	5.7
U.S. Total	294	328	337	319	313	273

* Annual generation figures for years before 1998 do not include nonutility generation, which is not reported in the Electric Power Annual.

Solar Buildings

Technology Description

Solar building technologies deliver heat, electricity, light, hot water, and cooling to residential and commercial buildings. By combining solar thermal and electric building technologies with very energy-efficient construction methods, lighting, and appliances, it is possible to build "Zero Energy Homes" (see photo for a demonstration-home example). Zero Energy Buildings (residential and commercial) have a zero net need for off-site energy on an annual basis and also have no carbon emissions.

System Concepts

- In solar heating systems, solar-thermal collectors convert solar energy into heat at the point of use, usually for domestic hot water and space heating.
- In solar cooling systems, solar-thermal collectors convert solar energy into heat for absorption chillers or desiccant regeneration.
- In solar lighting systems, sunlight is transmitted into the interior of buildings using glazed apertures, light pipes, and/or optical fibers.

Representative Technologies

- Active solar-heating systems use pumps and controls to circulate a heat transfer fluid between the solar collector(s) and storage. System sizes can range from 1 to 100 kW.
- Passive solar-heating systems do not use pumps and controls but rather rely on natural circulation to transfer heat into storage. System sizes can range from 1 to 10 kW.
- Transpired solar collectors heat ventilation air for industrial and commercial building applications. A transpired collector is a thin sheet of perforated metal that absorbs solar radiation and heats fresh air drawn through its perforations.
- Hybrid solar lighting systems focus concentrated sunlight on optical fibers in order to combine natural daylight with conventional illumination. Hybrid Solar Lighting (HSL) has the potential to more than double the efficiency and affordability of solar energy in commercial buildings by simultaneously separating and using different portions of the solar-energy spectrum for different end-use purposes, i.e. lighting and distributed power generation.

Technology Applications

- More than 1,000 MW of solar water-heating systems are operating successfully in the United States, generating more than 3 million MW-hrs per year.
- Based on peer-reviewed market penetration estimates, there will be approximately 1 million new solar water-heating systems installed by 2020, offering an energy savings of 0.16 quads (164 trillion Btus).
- Retrofit markets: There are 72.5 million existing single-family homes in the United States. An estimate of the potential replacement market of 29 million solar water-heating systems assumes that only 40% of these existing homes have suitable orientation and nonshading. (9.2 million replacement electric and gas water heaters.)
- New construction: In 2000, 1.2 million new single-family homes were built in the United States. Assuming 70% of these new homes could be sited to enable proper orientation of solar water-heating systems, this presents another 840,000 possible system installations annually.
- While the ultimate market for the zero-energy building concept is all new building construction; the near-term focus is on residential buildings; particularly, single-family homes in the Sunbelt areas of the

country. Of the 1.2 million new single-family homes built in the United States in 2000, 44% of these new homes were in the southern region of the country and 25% were in the western region, both areas with favorable solar resources.

Current Status

- About 1.2 million solar water-heating systems have been installed in the United States, mostly in the 1970s and 1980s. Due to relatively low energy prices and other factors, there are approximately only 8,000 installations per year.
- Typical residential solar systems use glazed flat-plate collectors combined with storage tanks to provide 40% to 70% of residential water-heating requirements. Typical systems generate 2500 kWh of energy per year and cost $1 to $2/Watt.
- Typical solar pool-heating systems use unglazed polymer collectors to provide 50% to 100% of residential pool-heating requirements. Typical systems generate 1,600 therms or 46,000 kWh of energy per year and cost $0.30 to $0.50/Watt
- Four multidisciplinary homebuilding teams have begun the initial phase of designing and constructing "Zero Energy Homes" for various new construction markets in the United States. One homebuilder (Shea Homes in San Diego) is currently building, and quickly selling, 300 houses with Zero Energy Home features—solar electric systems, solar water heating, and energy-efficient construction.
- Key companies developing or selling solar water heaters include:

Alternative Energy Technologies	Harter Industries
Aquatherm	Duke Solar
FAFCO	Heliodyne, Inc.
Radco Products	Sun Earth
Sun Systems	Thermal Conversion Technologies

Technology History

- 1890s- First commercially available solar water heaters produced in southern California. Initial designs were roof-mounted tanks and later glazed tubular solar collectors in thermosiphon configuration. Several thousand systems were sold to homeowners.
- 1900s- Solar water-heating technology advanced to roughly its present design in 1908 when William J. Bailey of the Carnegie Steel Company, invented a collector with an insulated box and copper coils.
- 1940s- Bailey sold 4,000 units by the end of WWI, and a Florida businessperson who bought the patent rights sold nearly 60,000 units by 1941.
- 1950s- Industry virtually expires due to inability to compete against cheap and available natural gas and electric service.
- 1970s- The modern solar industry began in response to the OPEC oil embargo in 1973-74, with a number of federal and state incentives established to promote solar energy. President Jimmy Carter put solar water-heating panels on the White House. FAFCO, a California company specializing in solar pool heating; and Solaron, a Colorado company that specialized in solar space and water heating, became the first national solar manufacturers in the United States. In 1974, more than 20 companies started production of flat-plate solar collectors, most using active systems with antifreeze capabilities. Sales in 1979 were estimated at 50,000 systems. In Israel, Japan, and Australia, commercial markets and manufacturing had developed with fairly widespread use.
- 1980s- In 1980, the Solar Rating and Certification Corp (SRCC) was established for testing and certification of solar equipment to meet set standards. In 1984, the year before solar tax credits expired, an estimated 100,000-plus solar hot-water systems were sold. Incentives from the 1970s helped create the 150-business manufacturing industry for solar systems with more than $800 million in annual sales

by 1985. When the tax credits expired in 1985, the industry declined significantly. During the Gulf War, sales again increased by about 10% to 20% to its peak level, more than 11,000 square feet per year (sq.ft./yr) in 1989 and 1990.

- 1990s- Solar water-heating collector manufacturing activity declined slightly, but has hovered around 6,000 to 8,000 sq.ft./yr. Today's industry represents the few strong survivors: More than 1.2 million buildings in the United States have solar water-heating systems, and 250,000 solar-heated swimming pools exist. Unglazed, low-temperature solar water heaters for swimming pools have been a real success story, with more than a doubling of growth in square footage of collectors shipped from 1995 to 2001.

Reference: American Solar Energy Society and Solar Energy Industry Association

Technology Future

- Near-term solar heating and cooling RD&D goals are to reduce the costs of solar water-heating systems to 4¢/kWh from their current cost of 8¢/kWh using polymer materials and manufacturing enhancements. This corresponds to a 50% reduction in capital cost.
- Near-term Zero Energy Building RD&D goals are to reduce the annual energy bill for an average-size home to $600 by 2004.
- Near-term solar lighting RD&D goals are to reduce the costs of solar lighting systems to 5¢/kWh.
- Zero-energy building RD&D efforts are targeted to optimize various energy efficiency and renewable energy combinations, integrate solar technologies into building materials and the building envelope, and incorporate solar technologies into building codes and standards.
- Solar heating and cooling RD&D efforts are targeted to reduce manufacturing and installation costs, improve durability and lifetime, and provide advanced designs for system integration.

Solar Buildings

Market Data

U.S. Installations (Thousands of Sq. Ft.) — Source: EIA, *Renewable Energy Annual 1997- 2000- Table 16, REA 1996- Table 18, and REA 2000- Table 8.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
Annual									
DHW					765	595	462	373	
Pool Heaters					6,787	7,528	7,200	8,141	
Total Solar Thermal	18,283	19,166	11,021	7,136	7,162	7,759	7,396	8,046	
Cumulative									
DHW									
Pool Heaters									
Total Solar Thermal	62,829	153,035	199,459	233,386	241,002	249,139	256,895	265,748	

U.S. Annual Shipments (Thousand Sq. Ft.) — Source: *Energy Information Administration, Renewable Energy Annual 1997- Table 11, REA 1996 Table 16 and REA 2000 Table 9.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
Total	19,398		11,409	7,666	7,616	8,138	7,756	8,583	
Imports			1,562	2,037	1,930	2,102	2,206	2,352	
Exports	1,115		245	530	454	379	360	537	

U.S. Shipments by Cell Type (thousands of sq. ft.) — Source: *EIA Renewable Energy Annual 2000. Table 10.3 Solar-Thermal Collector Shipments by Type, Price, and Trade, 1974-1999.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
Low-Temperature Collectors	12,233		3,645	6,813	6,821	7,524	7,292	8,152	
Medium-Temperature Collectors	7,165		2,527	840	785	606	443	427	
High-Temperature Collectors			5,237	13	10	7	21	4	
Total	19,398		11,409	7,666	7,616	8,137	7,756	8,583	

U.S. Shipments of All Solar-Thermal Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)	Source: EIA, *Renewable Energy Annual 1997, 1999- 2000- Table 16, and REA 1998- Table 19.*							
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Market Sector									
Residential					6,874	7,360	7,165	7,773	
Commercial					682	768	517	785	
Industrial					54	7	62	18	
Utility					0	0	2	4	
Other					7	2	3	2	
Total					7,618	8,137	7,749	8,582	
End Use									
Pool Heating					6,787	7,528	7,200	8,141	
Hot Water					765	595	462	373	
Space Heating					57	9	66	42	
Space Cooling					0	0	0	0	
Combined Space and Water Heating					2	3	16	16	
Process Heating					3	0	0	5	
Electricity Generation					0	0	2	4	
Other					0	1	2	2	
Total					7,615	8,136	7,748	8,583	

U.S. Shipments of High Temperature Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)	Source: EIA, *Renewable Energy Annual 1997, 1999- 2000- Table 16, and REA 1998- Table 19.*								
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Market Sector									
Residential					0	0	0	0	
Commercial					7	7	18	0	
Industrial					2	0	0	0	

Utility					0	0	2	4	
Other					0	0	1	0	
Total					10	7	21	4	
End Use									
Pool Heating					0	0	0	0	
Hot Water					7	7	18	0	
Space Heating					0	0	0	0	
Space Cooling					0	0	0	0	
Combined Space and Water Heating					0	0	0	0	
Process Heating					2	0	0	0	
Electricity Generation					0	0	2	4	
Other					0	0	1	0	
Total					10	7	21	4	

U.S. Shipments of Medium-Temperature Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)

Source: EIA, *Renewable Energy Annual 1997, 1999- 2000- Table 16, and REA 1998- Table 19.*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Market Sector									
Residential					728	569	355	365	
Commercial					50	35	70	59	
Industrial					1	0	18	0	
Utility					0	0	0	0	
Other					7	2	0	2	
Total					786	606	443	426	
End Use									
Pool Heating					21	11	36	12	
Hot Water					754	588	384	373	
Space Heating					6	2	13	24	
Space Cooling					0	0	0	0	
Combined Space and Water Heating					2	3	8	16	

	1980	1985	1990	1995	1996	1997	1998	1999	2000
Process Heating					1	0	0	0	
Electricity Generation					0	0	0	0	
Other					0	1	1	2	
Total					784	605	442	427	

U.S. Shipments of Low-Temperature Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)

Source: EIA, *Renewable Energy Annual 1997, 1999- 2000- Table 16, and REA 1998- Table 19.*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Market Sector									
Residential					6,146	6,791	6,810	7,408	
Commercial					625	726	429	726	
Industrial					51	7	44	18	
Utility					0	0	0	0	
Other					0	0	2	0	
Total					6,822	7,524	7,285	8,152	
End Use									
Pool Heating					6,766	7,517	7,164	8,129	
Hot Water					4	0	60	0	
Space Heating					51	7	53	18	
Space Cooling					0	0	0	0	
Combined Space and Water Heating					0	0	8	0	
Process Heating					0	0	0	5	
Electricity Generation					0	0	0	0	
Other					0	0	0	0	
Total					6,821	7,524	7,285	8,152	

Technology Performance

Energy Production	1980	1985	1990	1995	2000	2005	2010	2015	2020
Source: *Arthur D. Little, Review of FY 2001 Office of Power Technology's Solar Buildings Program Planning Unit Summary, December 1999.*									
Energy Savings									
DHW (kWh/yr)					2,750				
Pool Heater (therms/yr)					1,600				

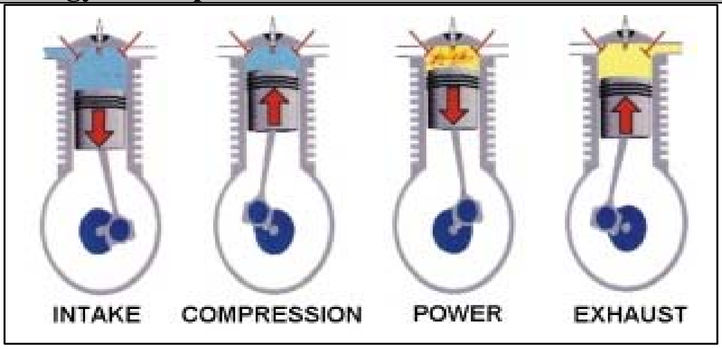
Cost	1980	1985	1990	1995	2000	2005	2010	2015	2020
Source: *Hot-Water Heater data from Arthur D. Little, Water-Heating Situation Analysis, November 1996, page 53, and Pool-Heater data from Ken Sheinkopf, Solar Today, Nov/Dec 1997, pp. 22-25.*									
Capital Cost* ($/System)									
Domestic Hot-Water Heater					1,900 - 2,500				
Pool Heater					3,300 - 4,000				
O&M ($/System-yr)									
Domestic Hot-Water Heater					25 - 30				
Pool Heater					0				

* Costs represent a range of technologies, with the lower bounds representing advanced technologies, such as a low-cost polymer integral collector for domestic hot-water heaters, which are expected to become commercially available after 2010.

Reciprocating Engines

Technology Description

Reciprocating engines, also known as internal combustion engines, require fuel, air, compression, and a combustion source to function. They make up the largest share of the small power generation market and can be used in a variety of applications due to their small size, low unit costs, and useful thermal output.



System Concepts

- Reciprocating engines fall into one of two categories depending on the ignition source: spark ignition (SI), typically fueled by gasoline or natural gas; or compression ignition (CI), typically fueled by diesel oil.
- Reciprocating engines also are categorized by the number of revolutions it takes to complete a combustion cycle. A two-stroke engine completes its combustion cycle in one revolution and a four-stroke engine completes the combustion process in two revolutions.

Representative Technologies

- The four-stroke SI engine has an intake, compression, power, and exhaust cycle. In the intake stroke, as the piston moves downward in its cylinder, the intake valve opens and the upper portion of the cylinder fills with fuel and air. When the piston returns upward in the compression cycle, the spark plug fires, igniting the fuel/air mixture. This controlled combustion forces the piston down in the power stroke, turning the crankshaft and producing useful shaft power. Finally the piston moves up again, exhausting the burnt fuel and air in the exhaust stroke.
- The four-stroke CI engine operates in a similar manner, except diesel fuel and air ignite when the piston compresses the mixture to a critical pressure. At this pressure, no spark or ignition system is needed because the mixture ignites spontaneously, providing the energy to push the piston down in the power stroke.
- The two-stroke engine, whether SI or CI, has a higher power density, because it requires half as many crankshaft revolutions to produce power. However, two-stroke engines are prone to let more fuel pass through, resulting in higher hydrocarbon emissions in the form of unburned fuel.

Technology Applications

- Reciprocating engines can be installed to accommodate baseload, peaking, or standby power applications. Commercially available engines range in size from 50 kW to 6.5 MW making them suitable for many distributed-power applications. Utility substations and small municipalities can install engines to provide baseload or peak shaving power. However, the most promising markets for reciprocating engines are on-site at commercial, industrial, and institutional facilities. With fast start-up time, reciprocating engines can play integral backup roles in many building energy systems. On-site reciprocating engines become even more attractive in regions with high electric rates (energy/demand charges).
- When properly treated, the engines can run on fuel generated by waste treatment (methane) and other biofuels.
- By using the recuperators that capture and return waste exhaust heat, reciprocating engines can be used in combined heat and power (CHP) systems to achieve energy efficiency levels approaching 80%. In fact, reciprocating engines make up a large portion of the CHP or cogeneration market.

Current Status

- Commercially available engines have electrical efficiencies (LHV) between 37% and 40% and yield NOx emissions of 1-2 grams per horsepower hour (hp-hr).
- Installed cost for reciprocating engines range between $600 and $1,600/ kW depending on size and whether the unit is for a straight generation or cogeneration application. Operating and maintenance costs range 2 cents to 2.5 cents/kWh.
- Exhaust temperature for most reciprocating engines is 700-1200° F in non-CHP mode and 350-500°F in a CHP system after heat recovery.
- Noise levels with sound enclosures are typically between 70-80 dB.
- The reciprocating-engine systems typically include several major parts: fuel storage, handling, and conditioning, prime mover (engine), emission controls, waste recovery (CHP systems) and rejections (radiators), and electrical switchgear.
- Annual shipments of reciprocating engines (sized 10GW or less) have almost doubled to 18 GW between 1997 and 2000. The growth is overwhelming in the diesel market, which represented 16 GW shipments compared with 2 GW of natural gas reciprocating engine shipments in 2000.

(*Source: Diesel and Gas Turbine Worldwide*).

Key indicators for stationary reciprocating engines:

Installed Worldwide Capacity	Installed US Capacity	Number of CHP sites using Recips in the U.S.
146 GW	52 GW	1,022

Source: Distributed Generation: The Power Paradigm for the New Millenium, 2001

Manufacturers of reciprocating engines include:

Caterpillar	Jenbacher
Cummins	Wartsila
Detroit Diesel	Waukesha

Technology History

- Natural gas-reciprocating engines have been used for power generation since the 1940s. The earliest engines were derived from diesel blocks and incorporated the same components of the diesel engine. Spark plugs and carburetors replaced fuel injectors, and lower compression–ratio pistons were substituted to run the engine on gaseous fuels. These engines were designed to run without regard to fuel efficiency or emission levels. They were used mainly to produce power at local utilities and to drive pumps and compressors.
- In the mid-1980s, manufacturers were facing pressure to lower NOx emissions and increase fuel economy. Leaner air-fuel mixtures were developed using turbochargers and charge air coolers, and in combination with lower in-cylinder fire temperatures, the engines reduced NOx from 20 to 5 g/bhp-hr. The lower in-cylinder fire temperatures also meant that the BMEP (Brake Mean Effective Pressure) could increase without damaging the valves and manifolds.
- Reciprocating-engine sales have grown more then five-fold from 1988 (2 GW) to 1998 (11.5 GW). Gas-fired engine sales in 1990 were 4% compared to 14% in 1998. The trend is likely to continue for gas-fired reciprocating engines due to strict air-emission regulations and because performance has been steadily improving for the past 15 years.

Technology Future
The U.S. Department of Energy, in partnership with the Gas Technology Institute, the Southwest Research Institute, and equipment manufacturers, supports the Advanced Reciprocating Engines Systems (ARES) consortium, aimed at further advancing the performance of the engine. Performance targets include: *High Efficiency*- Target fuel-to-electricity conversion efficiency (LHV) is 50 % by 2010. *Environment* – Engine improvements in efficiency, combustion strategy, and emissions reductions will substantially reduce overall emissions to the environments. The NOx target for the ARES program is 0.1 g/hp-hr, a 90% decrease from today's NOx emissions rate. *Fuel Flexibility* – Natural gas-fired engines are to be adapted to handle biogas, renewables, propane and hydrogen, as well as dual fuel capabilities. *Cost of Power* – The target for energy costs, including operating and maintenance costs is 10 % less than current state-of-the-art engine systems. *Availability, Reliability, and Maintainability* – The goal is to maintain levels equivalents to current state-of-the-art systems. Other R&D directions include: new turbocharger methods, heat recovery equipment specific to the reciprocating engine, alternate ignition system, emission-control technologies, improved generator technology, frequency inverters, controls/sensors, higher compression ratio, and dedicated natural-gas cylinder heads.

Reciprocating Engines

Technology Performance

Power Ranges (kW) of Selected Manufacturers — Source: Manufacturer Specs

	Low	High
Caterpillar	150	3,350
Waukesha	200	2,800
Cummins	5	1,750
Jenbacher	200	2,600
Wartsila	500	5,000

Market Data

Market Shipments
(GW of units under 10 MW in size)

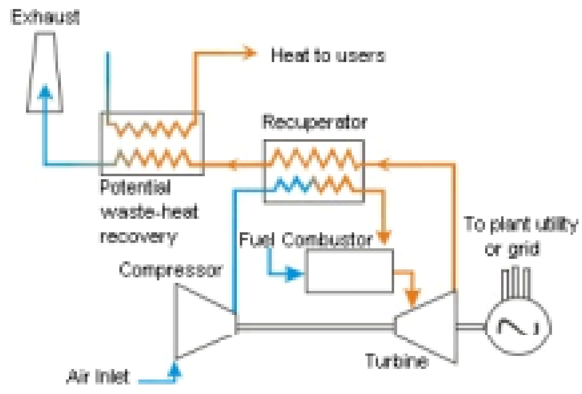
Source: Debbie Haught, DOE, communication 2/26/02 - from Diesel and Gas Turbine Worldwide.

	1996	1997	1998	1999	2000
Diesel Recips	7.96	7.51	8.23	10.02	16.46
Gas Recips	0.73	1.35	1.19	1.63	2.07

Microturbines

Technology Description

Microturbines are small combustion turbines of a size comparable to a refrigerator and with outputs of 25 kW to 500 kW. They are used for stationary energy generation applications at sites with space limitations for power production. They are fuel-flexible machines that can run on natural gas, biogas, propane, butane, diesel, and kerosene. Microturbines have few moving parts, high efficiency, low emissions, low electricity costs, and waste heat utilization opportunities; and are lightweight and compact in size. Waste heat recovery can be used in combined heat and power (CHP) systems to achieve energy efficiency levels greater than 80%.



System Concepts

- Microturbines consist of a compressor, combustor, turbine, alternator, recuperator, and generator.
- Microturbines are classified by the physical arrangement of the component parts: single shaft or two-shaft, simple cycle or recuperated, inter-cooled, and reheat. The machines generally operate at more than 40,000 rpm.
- A single shaft is the more common design because it is simpler and less expensive to build. Conversely, the split shaft is necessary for machine-drive applications, which do not require an inverter to change the frequency of the AC power.
- Efficiency gains can be achieved with greater use of materials like ceramics, which perform well at higher engine-operating temperatures.

Representative Technologies

- Microturbines in a simple cycle, or unrecuperated, turbine; compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. Simple-cycle microturbines have lower cost, higher reliability, and more heat available for CHP applications than recuperated units.
- Recuperated units use a sheet-metal heat exchanger that recovers some of the heat from an exhaust stream and transfers it to the incoming air stream. The preheated air is then used in the combustion process. If the air is preheated, less fuel is necessary to raise its temperature to the required level at the turbine inlet. Recuperated units have a higher efficiency and thermal-to-electric ratio than unrecuperated units, and yield 30-40% fuel savings from preheating.

Technology Applications

- Microturbines can be used in a wide range of applications in the commercial, industrial, and institutional sectors, microgrid power parks, remote off-grid locations, and premium power markets.
- Microturbines can be used for backup power, baseload power, premium power, remote power, cooling and heating power, mechanical drive, and use of wastes and biofuels.
- Microturbines can be paired with other distributed energy resources such as energy-storage devices and thermally activated technologies.

Current Status

- Microturbine systems are just entering the market and the manufacturers are targeting both traditional and nontraditional applications in the industrial and buildings sectors, including CHP, backup power, continuous power generation, and peak shaving.
- The most popular microturbine installed to date is the 30-kW system manufactured by Capstone.
- The typical 30-60 kW unit cost averages $1,000/kW. For gas-fired microturbines, the present installation cost (site preparation and natural gas hookup) for a typical commercial site averages $8,200.
- Honeywell pulled out of the microturbine business in December 2001, leaving the following manufacturers in the microturbine market:

Capstone Turbine Corporation	Ingersoll-Rand
DTE Energy Technologies	UTRC
Elliot Energy Systems	Bowman Power
Turbec	

- Capstone, Ingersoll-Rand, Elliott, and Turbec combined have shipped more than 2,100 units (156 MW) worldwide during the past four years.

Technology History

- Microturbines represent a relatively new technology, which is just making the transition to commercial markets. The technology used in microturbines is derived from aircraft auxiliary power systems, diesel-engine turbochargers, and automotive designs.
- In 1988, Capstone Turbine Corporation began developing the microturbine concept; and in 1998, Capstone was the first manufacturer to offer commercial power products using microturbine technology.

Technology Future

- The market for microturbines is expected to range from $2.4-to-$8 billion by 2010, with 50% of sales concentrated in North America.
- The acceptable cost target for microturbine energy is $0.05/kWh, which would present a cost advantage over most nonbaseload utility power.
- The next generation of "ultra-clean, high-efficiency" microturbine product designs will focus on the following DOE performance targets:
  - High Efficiency — Fuel-to-electricity conversion efficiency of at least 40%.
  - Environment — NOx < 7 ppm (natural gas).
  - Durability — 1,000 hours of reliable operations between major overhauls and a service life of at least 45,000 hours.
  - Cost of Power — System costs < $500/kW, costs of electricity that are competitive with alternatives (including grid) for market applications by 2005 (for units in the 30-60 kW range)
  - Fuel Flexibility — Options for using multiple fuels including diesel, ethanol, landfill gas, and biofuels.

Microturbines

Market Data

Microturbine Shipments	Source: Debbie Haught, communications 2/26/02. Capstone sales reported in Quarterly SEC filings, others estimated.				
# of units		**1998**	**1999**	**2000**	**2001**
Capstone		2	211	790	1033
Other Manufacturers					120
MW					
Capstone			6	23.7	38.1
Other Manufacturers					10.2

Technology Performance

Source: Manufacturer Surveys, Arthur D. Little (ADL) estimates.

Current System Efficiency (%)	LHV: 17-20% unrecuperated, 25-30%+ recuperated	
Lifetime (years)	5-10 years, depending on duty cycle	
Emissions (natural gas fuel)	Current	Future (2010
CO_2	670 - 1,180 g/kWh (17-30% efficiency)	
SO_2	Negligible (natural gas)	Negligible
NO_x	9-25 ppm	<9 ppm
CO	25-50 ppm	<9 ppm
PM	Negligible	Negligible
Typical System Size	Current Products: 25-100 kW Units can be bundled or "ganged" to produce power in larger increments	Future Products: up to 1 MW
Maintenance Requirements (Expected)	10,000-12,000 hr before major overhaul (rotor replacement)	
Footprint [ft^2/kW]	0.2-0.4	

Technology Performance

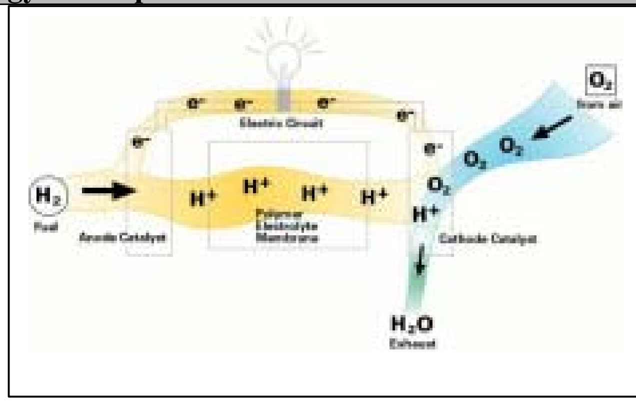
Sources: Debbie Haught, DOE, communication 2/26/02 and Energetics, Inc. *Distributed Energy Technology Simulator: Microturbine Validation*, July 12 2001.

	Capstone Turbine Corporation		Elliot Energy Systems	Ingersoll-Rand Energy Services	Turbec	DTE Energy Technologies
Model Name	Model 330	Capstone 60	TA-80	PowerWorks		ENT 400 recuperated
Size	30 kW	60 kW	80 kW	70 kW	100 kW	300 kW
Voltage	400-480 VAC				400 VAC	480/277 VAC
Fuel Flexibility	natural gas, medium Btu gas, diesel, kerosene		natural gas	natural gas	natural gas, biogas, ethanol, diesel	natural gas (diesel, propane future)
Fuel Efficiency (cf/kWh)	13.73	14.23			11.2	
Efficiency	26% (+/-2%)	28% (+/- 2%)	28%	30-33%	30%	28% (+/- 2%)
	70-90% CHP	70-90% CHP	80% CHP		80% CHP	74% CHP
Emissions	NO_x <9ppmV @15% O_2		NO_x diesel <60ppm, NO_x NG <25ppm, CO diesel <400ppm, CO NG <85ppm	NO_x <9ppmV @15% O_2, CO <9ppmV @15% O_2	NO_x <15ppmV @15% O_2, CO <15ppm, UHC <10ppm	NOx <9ppmV @15% O_2
Units Sold	1999: 211 units			2000: 2 precommercial units, expected commercial in 2001	2000: 20 units in the European market	Available late 2001
	2000: 790 units					
	2001: 1,033 units		2001: 100 units			
Unit Cost	$1000/kW				$75,000	
Cold Start-Up Time	3 min					3 min emergency, 7 min normal
Web site	www.capstone.com		www.elliott-turbo.com/new/products_microtubines.html	www.irco.com/energysystems/powerworks.html	www.turbec.com	www.dtetech.com/energynow/portfolio/2_1_4.asp

Fuel Cells

Technology Description

A fuel cell is an electrochemical energy conversion device that converts hydrogen and oxygen into electricity and water. This unique process is practically silent, nearly eliminates emissions, and has no moving parts.



System Concepts

- Similar to a battery, fuel cells have an anode and a cathode separated by an electrolyte.
- Hydrogen enters the anode and air (oxygen) enters the cathode. The hydrogen and oxygen are separated into ions and electrons, in the presence of a catalyst. Ions are conducted through the electrolyte while the electrons flow through the anode and the cathode via an external circuit. The current produced can be utilized for electricity. The ions and electrons then recombine, with water and heat as the only byproducts.
- Fuel cell systems today typically consist of a fuel processor, fuel cell stack, and power conditioner. The fuel processor, or reformer, converts hydrocarbon fuels to a mixture of hydrogen-rich gases and, depending on the type of fuel cell, can remove contaminants to provide pure hydrogen. The fuel cell stack is where the hydrogen and oxygen electrochemically combine to produce electricity. The electricity produced is direct current (DC) and the power conditioner converts the DC electricity to alternating current (AC) electricity, for which most of the end-use technologies are designed. As a hydrogen infrastructure emerges, the need for the reformer will disappear as pure hydrogen will be available near point of use.

Representative Technologies

Fuel cells are categorized by the kind of electrolyte they use.

Alkaline Fuel Cells (AFCs) were the first type of fuel cell to be used in space applications. AFCs contain a potassium hydroxide (KOH) solution as the electrolyte and operate at temperatures between 60 and 250°C (140 to 482°F). The fuel supplied to an AFC must be pure hydrogen. Carbon monoxide poisons an AFC, and carbon dioxide (even the small amount in the air) reacts with the electrolyte to form potassium carbonate.

Phosphoric Acid Fuel Cells (PAFCs) were the first fuel cells to be commercialized. These fuel cells operate at 150-220°C (302-428°F) and achieve 35 to 45% fuel-to-electricity efficiencies LHV.

Proton Exchange Membrane Fuel Cells (PEMFCs) operate at relatively low temperatures of 70-100°C (158-212°F), have high power density, can vary their output quickly to meet shifts in power demand, and are suited for applications where quick start-up is required (e.g., transportation and power generation). The PEM is a thin fluorinated plastic sheet that allows hydrogen ions (protons) to pass through it. The membrane is coated on both sides with highly dispersed metal alloy particles (mostly platinum) that are active catalysts.

Molten Carbonate Fuel Cell (MCFC) technology has the potential to reach fuel-to-electricity efficiencies of 45 to 60% on a lower heating value basis (LHV). Operating temperatures for MCFCs are around 650° C (1,200°F), which allows total system thermal efficiencies up to 85% LHV in combined-cycle applications. MCFCs have been operated on hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products.

Solid Oxide Fuel Cells (SOFCs) operate at temperatures up to 1,000°C (1,800°F), which further enhances combined-cycle performance. A solid oxide system usually uses a hard ceramic material instead of a liquid electrolyte. The solid-state ceramic construction enables the high temperatures, allows more flexibility in fuel choice, and contributes to stability and reliability. As with MCFCs, SOFCs are capable of fuel-to-electricity efficiencies of 45 to 60% LHV and total system thermal efficiencies up to 85% LHV in combined-cycle applications.

Technology Applications

- Fuel cell systems can be sized for grid-connected applications or customer-sited applications in residential, commercial, and industrial facilities. Depending on the type of fuel cell (most likely SOFC and MCFC), useful heat can be captured and used in combined heat and power systems (CHP).
- Premium power applications are an important niche market for fuel cells. Multiple fuel cells can be used to provide extremely high (more then six-nines) reliability and high-quality power for critical loads.
- Data centers and sensitive manufacturing processes are ideal settings for fuel cells.
- Fuel cells also can provide power for vehicles and portable power. PEMFCs are a leading candidate for powering the next generation of vehicles. The military is interested in the high-efficiency, low-noise, small-footprint portable power.

Current Status

- Fuel cells are still too expensive to compete in widespread domestic and international markets without significant subsidies.
- PAFC – More than 170 PAFC systems are in service worldwide, with those installed by ONSI having surpassed 2 million total operating hours with excellent operational characteristics and high availability.

Economic Specifications of the PAFC (200 kW)

Expense	Description	Cost
Capital Cost	1 complete PAFC power plant	$850,000
Installation	Electrical, plumbing, and foundation	$40,000
Operation	Natural gas costs	$5.35/MMcf
Minor Maintenance	Service events, semiannual and annual maintenance	$20,000/yr
Major Overhaul	Replacement of the cell stack	$320,000/5 yrs

Source: Energetics, *Distributed Energy Technology Simulator: Phosphoric Acid Fuel Cell Validation*, May 2001.

PEMFC – Ballard's first 250 kW commercial unit is under test. PEM systems up to 200 kW are also operating in several hydrogen-powered buses. Most units are small (<10 kW). PEMFCs currently cost several thousand dollars per kW.
SOFC – A small, 25 kW natural gas tubular SOFC systems has accumulated more than 70,000 hours of operations, displaying all the essential systems parameters needed to proceed to commercial configurations. Both 5 kW and 250 kW models are in demonstration.
MCFC – 50 kW and 2 MW systems have been field-tested. Commercial offerings in the 250 kW-2 MW range are under development.

Some fuel cell developers include:

Avista Laboratories	H Power
Ball Aerospace and Technologies Corp.	IdaTech
Ballard Power Systems, Inc	M-C Power
BCS Technology, Inc.	ONSI Corporation (IFC/United Technologies)
Ceramatec	Plug Power, LLC
DCH Technology, Inc	Proton Energy Systems
FuelCell Energy	Siemens Westinghouse Power Corporation

Fuel Cell Type	Electrolyte	Operating Temp (°C)	Electrical Efficiency (% LHV)	Commercial Availability	Typical Unit Size Range	Start-up time (hours)
AFC	KOH	60-250		1960s		
PEMFC	Nafion	70-100	35-45	2000-2001	5-250 kW	< 0.1
PAFC	Phosphoric Acid	150-220	35-45	1993	200 kW	1-4
MCFC	Lithium, potassium, carbonate salt	600-650	45-60	Post 2003	250 kW-2 MW	5-10
SOFC	Yttrium & zirconium oxides	800-1000	45-60	Post 2003	5-250 kW	5-10

Sources: Anne Marie Borbely and Jan F. Kreider. *Distributed Generation: The Power Paradigm for the New Millennium*, CRC Press, 2001, and Arthur D. Little, Distributed Generation Primer: Building the Factual Foundation (multiclient study), February 2000

Technology History

- In 1839, William Grove, a British jurist and amateur physicist, first discovered the principle of the fuel cell. Grove utilized four large cells, each containing hydrogen and oxygen, to produce electric power which was then used to split the water in the smaller upper cell into hydrogen and oxygen.
- In the 1960s, alkaline fuel cells were developed for space applications that required strict environmental and efficiency performance. The successful demonstration of the fuel cells in space led to their serious consideration for terrestrial applications in the 1970s.
- In the early 1970s, DuPont introduced the Nafion® membrane, which has traditionally become the electrolyte for PEMFC.
- In 1993, ONSI introduced the first commercially available PAFC. Its collaborative agreement with the U.S. Department of Defense enabled more than 100 PAFCs to be installed and operated at military installations.
- The emergence of new fuel cell types (SOFC, MCFC) in the past decade has led to a tremendous expansion of potential products and applications for fuel cells.

Technology Future

- According to the Business Communications Company, the market for fuel cells was about $218 million in 2000, will increase to $2.4 billion by 2004, and will reach $7 billion by 2009.
- Fuel cells are being developed for stationary power generation through a partnership of the U.S DOE and the private sector.
- Industry will introduce high-temperature natural gas-fueled MCFC and SOFC at $1,000 -$1,500 per kW that are capable of 60% efficiency, ultra-low emissions, and 40,000 hour stack life.
- DOE is also working with industry to test and validate the PEM technology at the 1–kW level and to transfer technology to the Department of Defense. Other efforts include raising the operating temperature of the PEM fuel cell for building, cooling, heating, and power applications and improve reformer technologies to extract hydrogen from a variety of fuels, including natural gas, propane, and methanol.

Fuel Cells

Technology Performance

Source: Arthur D. Little (ADL) estimates, survey of equipment manufacturers.

Only industrial applications; table does not address residential/commercial-scale fuel cells.

Technology	Size Range (kW)	2000 Characteristics						2005 Characteristics					
		Installed Cost ($/kW)		Non-Fuel O&M (cents/kWh)		Electrical Efficiency (LHV)		Installed Cost ($/kW)		Non-Fuel O&M (cents/kWh)		Electrical Efficiency (LHV)	
		Low	High	Low	High	High	Low	Low	High	Low	High	High	Low
Low Temperature Fuel Cell (PEM)	200-250	2,000	3,000	1.5	2.0	40%	30%	1,000	2,000	1.0	1.8	43%	33%
High Temperature Fuel Cell (SOFC & MCFC)	250-1,000	NA						1,500	2,000	1.0	2.0	55%	45%

Source: Energetics, *Distributed Energy Technology Simulator: PAFC Validation,* May 2001.

	Size (kW)	Capital Cost	Installation (Site Preparation)	Operation Costs (Natural Gas)	Minor Maintenance	Major Overhaul
Installation of a commercially available PAFC	200	$850,000	$40,000	$5.35/MMcf	$20,000/yr	$320,000/5 yrs

Technology Performance

There have been more than 25 fuel cell demonstrations funded by the private sector, the government, or a cofunded partnership of both. The objectives for most have been to validate a specific technology advance or application, and most of these demonstrations have been funded by the Office of Fossil Energy.

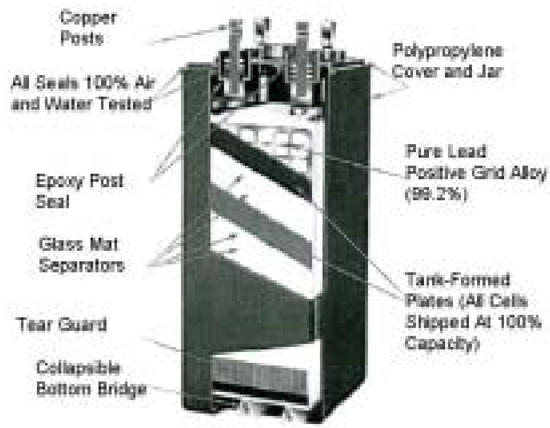
This is a listing of the demonstrations that have taken place between 1990 and today that have been published. All of the demonstrations were deemed a success, even if the testing had to end before its scheduled completion point. All of the manufacturers claimed they learned a great deal from each test. All the OPT-funded demonstrations were used to prove new higher performance-based technology either without lower catalyst levels, metal separator plates, carbon paper in lieu of machined carbon plates, or new membrane materials. Only the Plug Power fuel cell tested for the Remote Power Project failed, due to an electrical fire.

Fuel Cell Type	**Company**	**Objective**
Phosphoric Acid Fuel Cell	UT Fuel Cells (IFC)/FE	12.5 kW prototype using a new membrane assembly. (60 units) 40 kW power plant (46 units) 100 kW prototype for Georgetown Bus. (2 units) Methanol 200 kW first manufacturing prototype for PC25 (4 units) including natural gas reformer
Phosphoric Acid Fuel Cell	IFC/OPT	200 kW hydrogen version of PC 25 without a reformer, lower cost assembly
Solid Oxide	Westinghouse/FE	2 MW SOFC at Toshiba for fuels and tubular geometry testing 100 kW plannar unit to test seals, Netherlands 250 kW hybrid(57/50) w/turbine SoCal Ed 250 kW tubular SOFC combined heat and power, Ontario Power
Molten Carbonate	Fuel Cell Energy/FE	250 kW 8,800 hours Danbury Ct. first precommercial prototype 3 MW four years to build, Lexington Clean Coal Project 2 MW San Diego failed early
Proton Exchange Membrane	Plug Power/OTT Plug Power/OPT	10 kW prototype for vehicles 50 kW unsuccessful 25 kW prototype for Alaska, integrated with diesel reformer 50 kW prototype for Las Vegas refueling station, integrated with natural gas reformer

Proton Exchange Membrane	IFC/OTT	10 kW prototype sent to LANL for evaluation 50 kW prototype sent to GM for evaluation, reduced Pt catalyst 75 kW prototype installed in Hundai SUV, prototype for all transportation devices
Proton Exchange Membrane	Schatz Energy Center/OPT	(3) 5 kW Personal Utility Vehicles, (1) 15 kW Neighborhood Electric Vehicle Palm Desert each incorporated different levels of Pt catalyst, different membranes, all hydrogen fueled 1.3 kW Portable Power Unit
Proton Exchange Membrane	Enable/OPT	(3) 100 W Portable Power Units to demonstrate radial design (2) 1.5 kW Portable Power Units incorporating the LANL adiabatic fuel cell design (1) 1 kW "air breather" design for wheelchair
Proton Exchange Membrane	Ballard: no DOE funds	(6) 250 kW 40 foot passenger buses, hydrogen fueled: 3 Chicago, 2 Vancouver, 1 Palm Desert (1) 100 kW powerplant for Ford "Think" car (1) 250 kW stationary powerplant new manufacturing design
Proton Exchange Membrane	Nuvera/OPT	3 kW powerplant using metal separator plate technology for Alaska evaluated by SNL and University of Alaska
Proton Exchange Membrane	Coleman Powermate/Ballard no DOE funds	(3) 1.3 kW precommercial prototype UPS systems, metal hydride storage, under evaluation at United Laboratories for rating
Proton Exchange Membrane	Reliant Energy	7.5 kW precommercial prototype of radial stack geometry with conductive plastic separator plates
Alkaline	Zetec	25 kW precommercial prototype to demonstrate regenerative carbon dioxide scrubber
Alkaline	Hamilton Standard/IFC	(100) 12.5 kW commercial units for NASA
Alkaline	Union Carbide	(2) 50 kW fuel cells for GM van and car

Batteries

Technology Description



Batteries are likely the most widely known type of energy storage. They all store and release electricity through electrochemical processes and come in a variety of shapes and sizes. Some are small enough to fit on a computer circuit board while others are large enough to power a submarine. Some batteries are used several times a day while others may sit idle for 10 or 20 years before they are ever used. Obviously for such a diversity of uses, a variety of battery types are necessary. But all of them work from the same basic principles.

System Concepts

Battery electrode plates, typically consisting of chemically reactive materials, are placed in an electrolyte, which facilitates the transfer of ions in the battery. The negative electrode gives up electrons during the discharge cycle. This flow of electrons creates electricity that is supplied to any load connected to the battery. The electrons are then transported to the positive electrode. This process is reversed during charging. Batteries store and deliver direct current (DC) electricity. Thus, power-conversion equipment is required to connect a battery to the alternating current (AC) electric grid.

Representative Technologies

- The most mature battery systems are based on lead-acid technology. There are two major kinds of lead acid batteries: flooded lead acid batteries and valve-regulated-lead-acid (VRLA) batteries.
- There are several rechargeable, advanced batteries under development for stationary and mobile applications, including lithium-ion, lithium polymer, nickel metal hydride, zinc-air, zinc-bromine, sodium sulfur, and sodium bromide.
- These advanced batteries offer potential advantages over lead acid batteries in terms of cost, energy density, footprint, lifetime, operating characteristics reduced maintenance, and improved performance.

Technology Applications

- Lead-acid batteries are the most common energy storage technology for stationary and mobile applications. They offer maximum efficiency and reliability for the widest variety of stationary applications: telecommunications, utility switchgear and control, uninterruptible power supplies (UPS), photovoltaic, and nuclear power plants. They provide instantaneous discharge for a few seconds or a few hours.
- Installations can be any size. The largest system to date is 20 MW. Lead-acid batteries provide power quality, reliability, peak shaving, spinning reserve, and other ancillary services. The disadvantages of the flooded lead-acid battery include the need for periodic addition of water, and the need for adequate ventilation since the batteries can give off hydrogen gas when charging.
- VRLA batteries are sealed batteries fitted with pressure-release valves. They have been called low-maintenance batteries because they do not require periodic adding of water. They can be stacked horizontally as well as vertically, resulting in a smaller footprint than flooded lead-acid batteries. Disadvantages include higher cost and increased sensitivity to the charging cycle used. High temperature results in reduced battery life and performance.

- Several advanced "flow batteries" are under development. The zinc-bromine battery consists of a zinc positive electrode and a bromine negative electrode separated by a microporous separator. An aqueous solution of zinc/bromide is circulated through the two compartments of the cell from two separate reservoirs. Zinc-bromine batteries are currently being demonstrated in a number of hybrid installations, with microturbines and diesel generators. Sodium bromide/sodium bromine batteries are similar to zinc-bromine batteries in function and are under development for large-scale, utility applications. The advantages of flow-battery technologies are low cost, modularity, scalability, transportability, low weight, flexible operation, and all components are easily recyclable. Their major disadvantages are a relatively low cycle efficiency.
- Other advanced batteries include the lithium-ion, lithium-polymer, and sodium-sulfur batteries. The advantages of lithium batteries include their high specific energy (four times that of lead-acid batteries) and charge retention. Sodium sulfur batteries operate at high temperature and are being tested for utility load-leveling applications.

Current Status

- Energy storage systems for large-scale power quality applications (~10 MW) are economically viable now with sales from one manufacturer doubling from 2000 to 2001.
- Lead-acid battery annual sales have tripled between 1993 and 2000. The relative importance of battery sales for switchgear and UPS applications shrunk during this period from 45% to 26% of annual sales by 2000. VRLA and flooded battery sales were 534 and 171 million dollars, respectively, in 2000. Recently, lead-acid battery manufacturers have seen sales drop with the collapse of the telecommunications bubble in 2001. They saw significant growth in sales in 2000, due to the demand from communications firms, and invested in production and marketing in anticipation of further growth.
- Many manufacturers have been subject to mergers and acquisitions. A few dozen manufacturers in the United States and abroad still make batteries.
- Government and private industry are currently developing a variety of advanced batteries for transportation and defense applications: lithium-ion, lithium polymer, nickel metal hydride, sodium metal chloride, sodium sulfur, and zinc bromine.
- Rechargeable lithium batteries already have been introduced in the market for consumer electronics and other portable equipment.
- There are two demonstration sites of ZBB's Zinc Bromine batteries in Michigan and two additional ones in Australia.

Representative Current Manufacturers

Flooded	VRLA	Nickel Cadmium, Lithium Ion	Zinc Bromine
East Penn Exide Rolls Trojan	Hawker GNB Panasonic Yuasa	SAFT Sanyo Panasonic	Medentia Powercell ZBB

Technology History

- Most historians date the invention of batteries to about 1800 when experiments by Alessandro Volta resulted in the generation of electrical current from chemical reactions between dissimilar metals.
- Secondary batteries date back to 1860 when Raymond Gaston Planté invented the lead-acid battery. His cell used two thin lead plates separated by rubber sheets. He rolled the combination up and immersed it in a dilute sulfuric acid solution. Initial capacity was extremely limited since the positive plate had little active material available for reaction.

- Others developed batteries using a paste of lead oxides for the positive plate active materials. This allowed much quicker formation and better plate efficiency than the solid Planté plate. Although the rudiments of the flooded lead-acid battery date back to the 1880s, there has been a continuing stream of improvements in the materials of construction and the manufacturing and formation processes.
- Since many of the problems with flooded lead-acid batteries involved electrolyte leakage, many attempts have been made to eliminate free acid in the battery. German researchers developed the gelled-electrolyte lead-acid battery (a type of VRLA) in the early 1960s. Working from a different approach, Gates Energy Products developed a spiral-wound VRLA cell, which represents the state of the art today.

Technology Future

- Lead-acid batteries provide the best long-term power in terms of cycles and float life and, as a result, will likely remain a strong technology in the future.
- Energy storage and battery systems in particular will play a significant role in the Distributed Energy Resource environment of the future. Local energy management and reliability are emerging as important economic incentives for companies.
- A contraction in sales of lead-acid batteries that began in 2001 was expected to continue over the next few years until 9/11 occurred. Military demand for batteries may drastically alter the forecast for battery sales.
- Battery manufacturers are working on incremental improvements in energy and power density. The battery industry is trying to improve manufacturing practices and build more batteries at lower costs to stay competitive. Gains in development of batteries for mobile applications will likely crossover to the stationary market.
- Zinc Bromine batteries are expected to be commercialized in 2003 with a target cost of $400/kWh. A 10 MW-120 MWh sodium bromide system is under construction by the Tennessee Valley Authority A 40 MW nickel cadmium system is being built for transmission-line support and stabilization in Alaska.

Batteries

Market Data

Recent Battery Sales Source: Battery Council International, Annual Sales Summary, October 2001.

	1993	2000	Growth
Flooded Batteries (Million $)	156.9	533.5	340%
VRLA Batteries (Million $)	79.6	170.6	214%
Total Lead-Acid Batteries (Million $)	236.5	704.1	298%

Percent Communications	58%	69%
Percent Switchgear/UPS	45%	26%

Market Predictions Source: Sandia National Laboratories, Battery Energy Storage Market Feasibility Study, September 1997.

Year	MW	($ Million)
2000	496	372
2005	805	443
2010	965	434

Technology Performance

Grid-Connected Energy Storage Technologies Costs and Efficiencies Source: Sandia National Laboratories, Characteristics and Technologies for Long- vs. Short-Term Energy Storage, March 2000.

Energy-Storage System	Energy Related Cost ($/kWh)	Power Related Cost ($/kW)	Balance of Plant ($/kWh)	Discharge Efficiency
Lead-acid Batteries				
low	175	200	50	0.85
average	225	250	50	0.85
high	250	300	50	0.85
Power-Quality Batteries	100	250	40	0.85
Advanced Batteries	245	300	40	0.7

Technology Performance

Off-Grid Storage Applications, Their Requirements, and Potential Markets to 2010 According to Boeing Source: Sandia National Laboratories, Energy Storage Systems Program Report for FY99, June 2000.

Application	Single Home: Developing Community	Developing Community: No Industry	Developing Community: Light Industry	Developing Community: Moderate Industry	Advanced Community or Military Base
Storage-System Attributes					
Power (kW)	0.5	8	40	400	1 MW
Energy (kWh)	3	45	240	3,600	1.5 MWh
Power					
Base (kW)	0.5	5	10	100	100
Peak (kW)		< 8	< 40	< 400	< 1000
Discharge Duration	5 to 72 hrs	5 to 72 hrs	5 to 24 hrs	5 to 24 hrs	0.5 to 1 hr
Total Projected Number of Systems	47 Million	137,000	40,000	84,000	131,000
Fraction of Market Captured by Storage	> 50	> 50	~ 30	~ 10	< 5
Total Number of Storage Systems to Capture Market Share	24 Million	69,000	12,000	8,000	< 7,000

Technology Performance

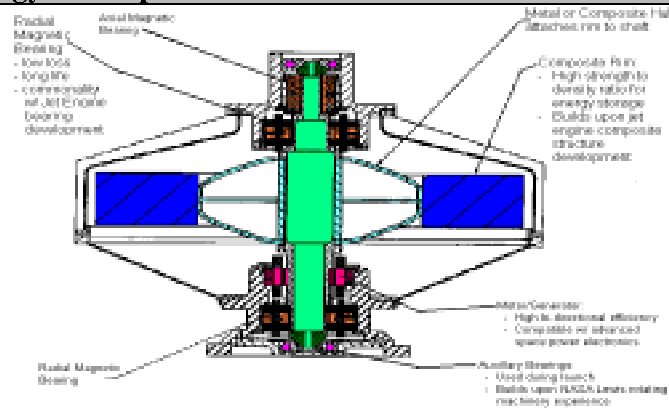
Advanced Batteries Characteristics Source: DOE Energy Storage Systems Program Annual Peer Review FY01, Boulder City Battery Energy Storage, November 2001.

Energy Storage System	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Field Experience	Over 30 Projects, 25 kW to 6 MW, Largest 48 MW	Several Projects 100kW to 3 MW (pulse power), Largest 1.15 MWh	Several Projects, 50 kW to 250 kW, Largest 400 kWh
Production Capacity	160 MWh/yr	30 MWh/yr	40 to 70 MWh/yr
Actual Production	50 MWh/yr	10 MWh/yr	4.5 MWh/yr
Life	15 yrs	7 to 15 yrs	10 to 20 yrs
Efficiency	72%	70to 80 %	65 to 70%
O&M Costs	$32.5k/yr	$50k/yr	$30 to $150k/yr

Advanced Energy Storage

Technology Description

The U.S. electric utility industry has been facing new challenges with deregulation and limitations on installing new transmission and distribution equipment. Advanced storage technologies under active development, in addition to advanced batteries, include processes that are mechanical (flywheels, pneumatic storage) and purely electrical (supercapacitors, super conducting magnetic storage), and compressed-air energy storage. These advanced energy-storage solutions will help achieve more reliable and low-cost electricity storage.



Flywheel Cutaway

System Concepts

Flywheels (Low-Speed and High-Speed)

Flywheels store kinetic energy in a rotating mass. The amount of stored energy is dependent on the speed, mass, and configuration of the flywheel. They have been used as short-term energy storage devices for propulsion applications such as engines for large road vehicles. Today, flywheel energy storage systems are usually categorized as either low-speed or high-speed. High-speed wheels are made of high strength, low-density composite materials, making these systems considerably more compact than those employing lower-speed metallic wheels. However, the low-speed systems are still considerably less expensive per kWh.

Supercapacitors

Supercapacitors are also known as Electric Double Layer Capacitors, pseudocapacitors, or ultracapacitors. Charge is stored electrostatically in polarized liquid layers between an ionically conducting electrolyte and a conducting electrode. Though they are electrochemical devices, no chemical reactions occur in the energy-storage mechanism. Since the rate of charge and discharge is determined solely by its physical properties, an ultracapacitor can release energy much faster (i.e., with more power) than a battery, which relies on slow chemical reactions. Ultracapacitors deliver up to 100 times the energy of a conventional capacitor and deliver 10 times the power of ordinary batteries.

Compressed-Air Energy Storage (CAES)

CAES systems store energy by compressing air within a reservoir using off peak/low cost electric energy. During charging, the plant's generator operates in reverse – as a motor – to send air into the reservoir. When the plant discharges, it uses the compressed air to operate the combustion turbine generator. Natural gas is burned during plant discharge in the same fashion as a conventional turbine plant. However, during discharge, the combustion turbine in a CAES plant uses all of its mechanical energy to generate electricity; thus, the system is more efficient. CAES is an attractive energy-storage technology for large-scale storage.

Superconducting Magnetic Energy Storage (SMES)

SMES systems store energy in the magnetic field created by the flow of direct current in a coil of superconducting material. SMES systems provide rapid response to either charge or discharge, and their available energy is independent of their discharge rate. SMES systems have a high cycle life and, as a result, are suitable for applications that require constant, full cycling and a continuous mode of operation. Micro-SMES devices in the range of 1 to 10 MW are available commercially for power-quality applications.

Representative Technologies

- While the system-concepts section addressed energy-storage components exclusively, all advanced storage systems require power conditioning and balance of plant components.
- For vehicle applications, flywheels, CAES, and ultracapacitors are under development.
- A dozen companies are actively developing flywheels. Steel, low-speed flywheels, are commercially available now; composite, high-speed flywheels are rapidly approaching commercialization.
- Pneumatic storage (CAES) is feasible for energy storage on the order of 100's MWh.
- Prototype ultracapacitors have recently become commercially available.

Technology Applications

- Energy available in SMES is independent of its discharge rating, which makes it very attractive for high power and short time burst applications such as power quality.
- SMES are also useful in transmission enhancement as they can provide line stability, voltage and frequency regulation, as well as phase angle control.
- Flywheels are primarily used in transportation, defense, and power quality applications.
- Load management is another area where advanced energy-storage systems are used (e.g., CAES). Energy stored during off-peak hours is discharged at peak hours, achieving savings in peak energy, demand charges, and a more uniform load.
- Load management also enables the deferral of equipment upgrades required to meet an expanding load base which typically only overloads equipment for a few hours a day.
- Ultracapacitors are used in consumer electronics, power quality, transportation, and defense and have potential applications in combination with distributed generation equipment for following rapid load changes.

Current Status

- Utilities require high reliability, and per-kilowatt costs less than or equal to those of new power generation ($400–$600/kW). Compressed gas energy storage can cost as little as $1–$5/kWh. SMES has targets of $150/kW and $275/kWh. Vehicles require storage costs of $300 to $1,000/kWh to achieve significant market penetration. The major hurdle for all storage technologies is cost reduction.
- Ultracapacitor development needs improved energy density from the current 1.9 W-h/kg for light-duty hybrid vehicles.
- Low-speed (7,000-9,000 rpm) steel flywheels are commercially available for power quality and UPS applications.
- There is one 110-MW CAES facility operated by an electric co-op in Alabama.
- ix SMES units have been installed in Wisconsin to stabilize a ring transmission system.

Representative Current Manufacturers

Flywheels	Supercapacitors	CAES	SMES
Active Power American Flywheel Systems Pillar	Nanolab Cooper Maxwell NEC	Ingersoll Rand ABB Dresser-Rand Alstrom	American Superconductor

Technology Future
• Developments in the vehicular systems will most likely crossover into the stationary market. • High-temperature (liquid-nitrogen temperatures) superconductors that are manufacturable and can carry high currents could reduce both capital and operating costs for SMES. • High-speed flywheels need further development of fail-safe designs and/or lightweight containment. Magnetic bearings will reduce parasitic loads and make flywheels attractive for small uninterruptible power supplies and small energy management applications. • Much of the R&D in advanced energy storage is being pursued outside the United States, in Europe, and Japan. U.S. government research funds have been very low, relative to industry investments. One exception has been the Defense Advanced Research Programs Agency, with its flywheel containment development effort with U.S. flywheel manufacturers, funded at $2 million annually. The total DOE Energy Storage Program budget hovers in the $4 million to $6 million range during the past 10 years.

Advanced Energy Storage

Market Data

Market Predictions

Source: Sandia National Laboratories, Cost Analysis of Energy-Storage Systems for Electric Utility Applications, February 1997.

Energy-Storage System	Present Cost	Projected Cost Reduction
SMES	$54,000/MJ	5-10%
Flywheels	$200/kWh	443

Technology Performance

Energy-Storage Costs and Efficiencies

Source: Sandia National Laboratories, Characteristics and Technologies for Long- vs. Short-Term Energy Storage, March 2000.

Energy-Storage System	Energy-Related Cost ($/kWh)	Power Related Cost ($/kW)	Balance of Plant ($/kWh)	Discharge Efficiency
Micro-SMES	72,000	300	10,000	0.95
Mid-SMES	2,000	300	1,500	0.95
SMES	500	300	100	0.95
Flywheels (high-speed)	25,000	350	1,000	0.93
Flywheels (low-speed)	300	280	80	0.9
Ultracapacitors	82,000	300	10,000	0.95
CAES	3	425	50	0.79

Technology Performance

Energy-Storage Technology Profiles

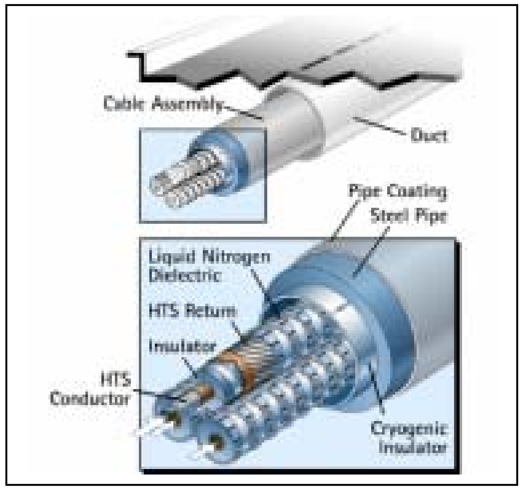
Source: DOE/EPRI, Renewable Energy Technology Characterizations, December 1997, Appendix A.

Technology	Installed U.S. Total	Facility Size Range	Potential/Actual Applications
Flywheels	1-2 demo facilities, no commercial sites. In 2002, steel flywheels with rotational speeds of 7000-9000 rpm are commercially available for power quality and UPS applications.	kW scale	Electricity (Power Quality) Transportation, Defense
SMES	5 facilities with approx. 30 MW in 5 states	From 1-10 MW (micro-SMES) to 10-100 MW	Electricity (T&D, Power Quality)
Ultracapacitors	Millions of units for standby power; 1 defense unit	7-10 W commercial 10-20 kW prototype	Transportation Defense Consumer Electronics Electricity (Power Quality)
CAES	110 MW in Alabama	25 MW to 350 MW	Electricity (Peak-shaving, Spinning Reserve, T&D)

Superconducting Power Technology

Technology Description

Superconducting power technology refers to electric power equipment and devices that use superconducting wires and coils. High Temperature Superconductivity (HTS) enables electricity generation, delivery, and end use without the resistance losses encountered in conventional wires made from copper or aluminum. HTS wires have the potential to carry 100 times the current without the resistance losses of comparable diameter copper wires. HTS power equipment, such as motors, generators, and transformers, has the potential to be half the size of conventional alternatives with the same power rating and only half the energy losses.



Source: American Superconductor

System Concepts

- HTS systems will be smaller, more efficient, and carry more power than a similarly rated conventional system.
- HTS systems will help the transmission and distribution system by allowing for greater power transfer capability, increased flexibility, and increased power reliability.

Representative Technologies

Transmission Cables	Current Limiters
Motors	Transformers
Generators	Flywheel Electricity Systems

Technology Applications

- Superconducting technology will modernize the electric grid and infrastructure, resulting in greater flexibility, efficiency, and cost effectiveness.
- Wire and Coils have reached a sufficient level of development to allow for their introduction into prototype applications of HTS systems such as motors, generators, transmission cables, current limiters, and transformers.
- Motors rated greater than 1,000 hp will primarily be used for pump and fan drives for utility and industrial markets.
- Current controllers will perform as a fast sub-cycle breaker when installed at strategic locations in the transmission and distribution system.
- Flywheel electricity systems can be applied to increase electric-utility efficiency in two areas—electric-load leveling and uninterruptible power systems (UPS) applications.
- Transformers are environmentally friendly and oil-free, making them particularly useful where transformers previously could not be sited, such as in high-density urban areas or inside buildings.
- Reciprocating Magnetic Separators can be used in the industrial processing of ores, waste solids, and waste gases, as well as performing isotope separations and water treatment.

Current Status

- Much of the research and development in HTS is focused on wire and system development and prototype system design and deployment.
- There are 18 manufacturers, eight National Laboratories, six utilities, and 17 universities participating in the U.S. Department of Energy Superconductivity Program alone. The list of manufacturers includes:

3M	ABB
American Superconductor	Pirelli Cables North America
IGC SuperPower	Waukesha Electric Systems
Southwire Company	

- Prototype power transmission cables have been developed and are being tested by two teams led by Pirelli Cable Company and Southwire Company respectively.
- A 1,000-horsepower prototype motor was produced and tested by Rockwell Automation/Reliance Electric Company. The results of these tests are being used to design a 5,000 hp motor.
- A team led by General Electric has developed a design for a 100 MW generator.
- A 15 kV current controller was tested at a Southern California Edison substation in July 1999.
- The design of a 3 kW/10 kWh flywheel system has been completed. The superconducting bearings, motor/generator, and control system have been constructed and are undergoing extensive testing. A rotor construction is underway.
- The design of the reciprocating magnetic separator has been finalized, and components for the system have been procured and assembled. The test site has been prepared, and cryogenic testing has begun.

Technology History

- In 1911, after technology allowed liquid helium to be produced, Dutch physicist Heike Kammerlingh Onnes found that at 4.2 K, the electrical resistance of mercury decreased to almost zero. This marked the first discovery of superconducting materials.
- Until 1986, superconductivity applications were highly limited due to the high cost of cooling to such low temperatures, which resulted in costs higher than the benefits of using the new technology.
- In 1986, two IBM scientists, J. George Bednorz and Karl Müller achieved superconductivity on lanthanum copper oxides doped with barium or strontium at temperatures as high as 38 K.
- In 1987, the compound $Y_1Ba_2Cu_3O_7$ (YBCO) was given considerable attention, as it possessed the highest critical temperature at that time, at 93 K. In the following years, other copper oxide variations were found, such as bismuth lead strontium calcium copper oxide (110 K), and thallium barium calcium copper oxide (125 K).
- In 1990, the first (dc) HTS motor was demonstrated.
- In 1992, a 1-meter-long HTS cable was demonstrated.
- By 1996, a 200-horsepower HTS motor was tested and exceeded its design goals by 60%.

Technology Future

Year of 50% Market Penetration

Motors	Transformers	Generators	Underground Cable
2016	2015	2021	2013

Source: ORNL/Sub/4500006921, 2000 Edition - High Temperature Superconductivity: The Products and Their Benefits.

- Low-cost, high-performance YBCO Coated Conductors will be available in 2005 in kilometer lengths.
- The present cost of HTS wire is $300/kA-m. By 2005, for applications in liquid nitrogen, the wire cost will be less than $50/kA-m; and for applications requiring cooling to temperatures of 20-60 K, the cost will be less than $30/kA-m.
- By 2010, the cost-performance ratio will have improved by at least a factor of four. The cost target is $10/kA-m.

Superconducting Power Technology

Market Data

Projected Market for HTS devices (Thousands of Dollars)

Source: U.S. Department of Energy, September 2001, Analysis of Future Markets for High-Temperature Superconductors, Draft.

Year	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**2023**	**2025**
Motors	228	956	4,025	15,399	50,968	108,429	148,770	164,072
Transformers	0	0	243	1,451	9,353	56,081	222,277	390,964
Generators	6,926	24,710	83,634	227,535	445,693	592,904	656,499	675,656
Cables	4,117	14,405	48,335	135,001	318,844	488,783	570,326	586,284
Total	11,270	40,071	136,236	379,386	824,857	1,246,196	1,597,872	1,816,975

Underground Power Cables: Market Penetration and Benefits

Case 1

Source: ORNL/Sub/4500006921, 2000 Edition – High-Temperature Superconductivity: The Products and Their Benefits

	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**
% Market	0	6.7	15	27	40	56	69	77	80
Miles Sold this Year	0	13.89	32.68	61.77	96.19	141.47	183.15	214.73	234.35
Total Miles Installed	0	20.76	74.69	183.34	356.96	616.75	963.05	1,379	1,839
Total Annual Savings (10^6 $)	0	0.165	0.582	1.4	2.68	4.56	6.98	9.82	12.86

Underground Power Cables: Market Penetration and Benefits									
Case 2	Source: ORNL/Sub/4500006921, 2000 Edition – High-Temperature Superconductivity: The Products and Their Benefits								
	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**
% Market	0	6.7	15	27	40	56	69	77	80
Miles Sold this Year	0	12.33	28.39	52.56	80.07	115.2	145.98	167.53	178.98
Total Miles Installed	0	18.42	65.49	158.36	303.55	516.13	793.6	1120	1473
Total Annual Savings (10^6 $)	0	0.145	0.506	1.2	2.261	3.778	5.698	7.897	10.2

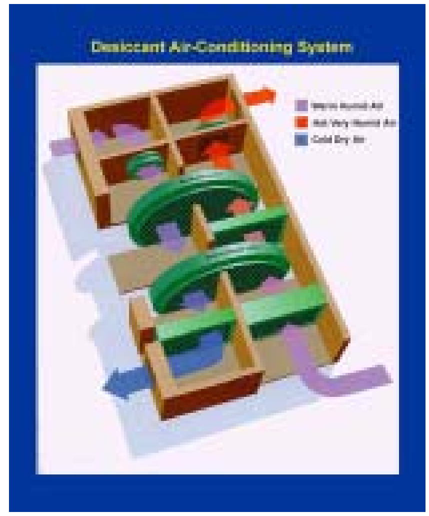
The first case is based on electrical generation and equipment market growth averaging 2.5% per year through 2020. This number was chosen based on historic figures from 1990-1998 and the assumption that a strong economy will continue this kind of growth. Case 2 follows present EIA projections of 1.4% growth, with somewhat more conservative results.

Technology Performance

HTS Energy Savings (GWh)	Source: U.S. Department of Energy, September 2001, Analysis of Future Markets for High-Temperature Superconductors, Draft.								
Year	**2009**	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**2023**	**2025**
Motors	0	0	1	4	15	57	154	300	468
Transformers	0	0	0	0	2	15	94	449	1,194
Generators	2	11	44	171	556	1,417	2,699	4,196	5,785
Cables	1	3	13	55	196	598	1,336	2,289	3,326
Total	3	14	58	231	769	2,086	4,283	7,235	10,774

Thermally Activated Technologies

Technology Description



Thermally Activated Technologies (TATs), such as heat pumps, absorption chillers, and desiccant units, provide on-site space conditioning and water heating, which greatly reduce the electric load of a residential or commercial facility. These technologies can greatly contribute to system reliability.

System Concepts

- TATs may be powered by natural gas, fuel oil, propane, or biogas, avoiding substantial energy conversion losses associated with electric power transmission, distribution, and generation.
- These technologies may use the waste heat from on-site power generation and provide total energy solutions for onsite cooling, heating, and power.

Representative Technologies

- Thermally activated heat pumps can revolutionize the way residential and commercial buildings are heated and cooled. This technology enables highly efficient heat pump cycles to replace the best natural gas furnaces, reducing energy use as much as 50%. Heat pumps take in heat at a lower temperature and release it a higher one, with a reversing valve that allows the heat pump to provide space heating or cooling as necessary. In the heating mode, heat is taken from outside air when the refrigerant evaporates and is delivered to the building interior when it condenses. In the cooling mode, the function of the two heat-exchanger coils is reversed, so heat moves inside to outside.
- Absorption chillers provide cooling to buildings by using heat. Unlike conventional electric chillers, which use mechanical energy in a vapor-compression process to provide refrigeration, absorption chillers primarily use heat energy with limited mechanical energy for pumping. The chiller transfers thermal energy from the heat source to the heat sink through an absorbent fluid and a refrigerant. The chiller achieves its refrigerative effect by absorbing and then releasing water vapor into and out of a lithium bromide solution. In the process, heat is applied at the generator and water vapor is driven off to a condenser. The cooled water vapor then passes through an expansion valve, reducing the pressure. The low-pressure water vapor then enters an evaporator, where ambient heat is added from a load and the actual cooling takes place. The heated, low-pressure vapor returns to the absorber, where it recombines with lithium bromide and becomes a low-pressure liquid. This low-pressure solution is pumped to a higher pressure and into the generator to repeat the process.
- Desiccant equipment is useful for mitigation of indoor air-quality problems and for improved humidity control in buildings. The desiccant is usually formed in a wheel made up of lightweight honeycomb or corrugated material (see figure). Commercially available desiccants include silica gel, activated alumina, natural and synthetic zeolites, lithium chloride, and synthetic polymers. The wheel is rotated through supply air, usually from the outside, and the material naturally attracts the moisture from the air before it is routed to the building. The desiccant is then regenerated using thermal energy from natural gas, the sun, or waste heat.

Technology Applications

- Thermally activated heat pumps are a new generation of advanced absorption cycle heat pumps that can efficiently condition residential and commercial space. Different heat pumps will be best suited for different applications. For example, the GAX heat pump is targeted for northern states because of its superior heating performance; and the Hi-Cool heat pump targets the South, where cooling is a priority.
- Absorption chillers can change a building's thermal and electric profile by shifting the cooling from an electric load to a thermal load. This shift can be very important for facilities with time-of-day electrical rates, high cooling-season rates, and high demand charges. Facilities with high thermal loads, such as data centers, grocery stores, and casinos, are promising markets for absorption chillers.
- Desiccant technology can either supplement a conventional air-conditioning system or act as a standalone operation. A desiccant can remove moisture, odors, and pollutants for a healthier and more comfortable indoor environment. Facilities with stringent indoor air-quality needs (schools, hospitals, grocery stores, hotels) have adapted desiccant technology.
- CHP applications are well suited for TATs. They offer a source of "free" fuel in the form of waste heat that can power heat pumps and absorption chillers, and regenerate desiccant units.

Current Status

Thermally activated heat pump technology can replace the best natural gas furnace and reduce energy use by as much as 50%, while also providing gas-fired technology.
Desiccant technology may be used in pharmaceutical manufacturing to extend the shelf life of products; refrigerated warehouses to prevent water vapor from forming on the walls, floors, and ceilings; operating rooms to remove moisture form the air, keeping duct work and sterile surfaces dry; and hotels, to prevent buildup of mold and mildew.
Companies that manufacture TAT equipment include:

York International	Broad
Trane	Air Technology Systems
Munters Corporation	American Power Conversion Company
Kathabar Systems	Goettl

Technology History

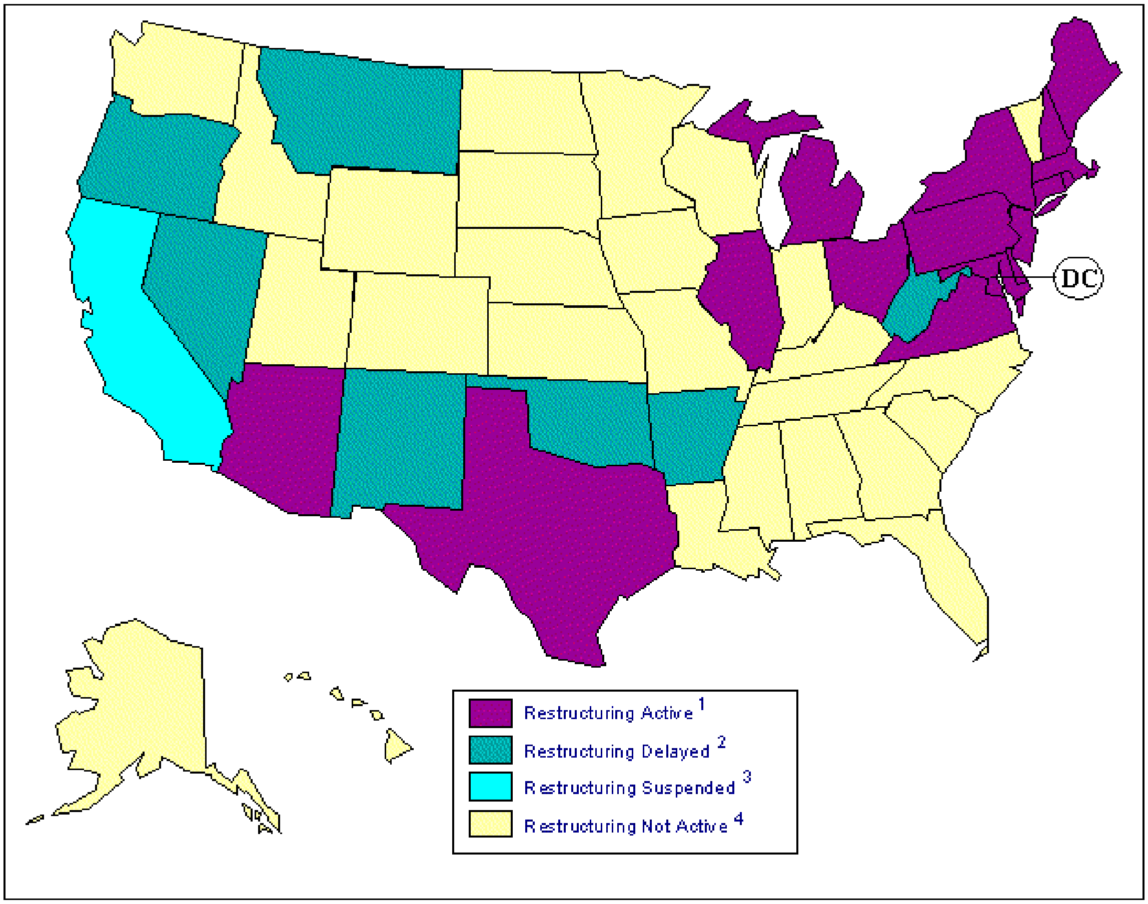
- In the 1930s, the concept of dehumidifying air by scrubbing it with lithium chloride was introduced, paving the way for development of the first desiccant unit.
- In 1970, Trane introduced a mass-produced, steam-fired, double-effect $LiBr/H_2O$ absorption chiller.
- In 1987, the National Appliance Energy Conversion Act instituted minimum efficiency standards for central air-conditioners and heat pumps.

Technology Future

- Expand the residential market of the second-generation Hi-Cool residential absorption heat pump technology to include markets in southern states; the targeted 30% improvement in cooling performance can only be achieved with major new advancements in absorption technology or with an engine-driven system.
- Work in parallel with the first-generation GAX effort to determine the most attractive second-generation Hi-Cool technology.
- Fabricate and test the 8-ton advanced cycle VX GAX ammonia/water heat pump.
- Fabricate and test the 3-ton complex compound heat pump and chiller.
- Develop, test, and market an advanced Double Condenser Coupled commercial chiller, which is expected to be 50% more efficient than conventional chillers.
- Assess new equipment designs and concepts for desiccants using diagnostic techniques, such as infrared thermal performance mapping and advanced tracer gas-leak detection.

3.0 Electricity Restructuring

3.1 - States with Competitive Electricity Markets



[1]These states have either enacted enabling legislation or issued a regulatory order to implement retail access. Retail access is either currently available to all or some customers or will soon be available. Some states are currently running pilot programs, and they will begin to implement retail access in the near future: Arizona, Connecticut, Delaware, District of Columbia, Illinois, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Texas, and Virginia.

[2]These states have either passed legislation or issued regulatory orders to delay implementing retail access: Arkansas, Montana, Nevada, New Mexico, Oklahoma, and Oregon. Although West Virginia passed legislation that approved the PSC's plan to restructure and implement retail access, the process is delayed until a bill for tax reform is enacted.

[3]The CPUC ordered suspension of direct retail access.

Source: U.S. DOE, Energy Information Administration
http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html , January 10, 2002.

3.2 - States with System Benefit Charges (SBC)

A System Benefit Charge (SBC) is a small fee added to a customer's electricity bill used to fund programs that benefit the public, such as low-income energy assistance, energy-efficiency and renewable energy. There are 14 states with SBCs through which a portion of the money will be used to support renewable resources. Together, these states will collect about $4 billion in funds to support renewable resources between 1998 and 2012.

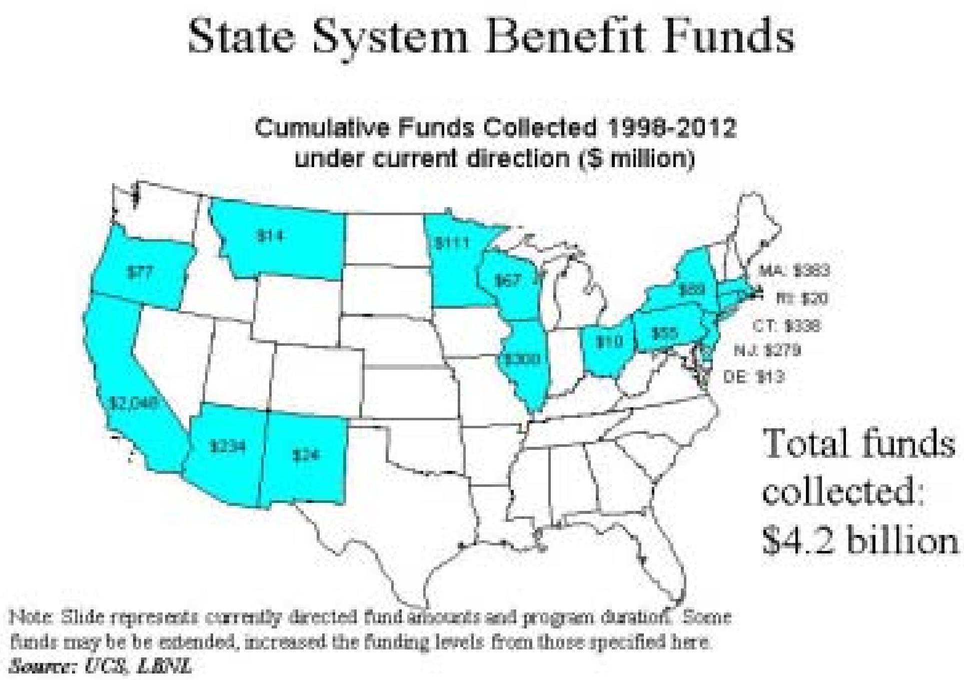
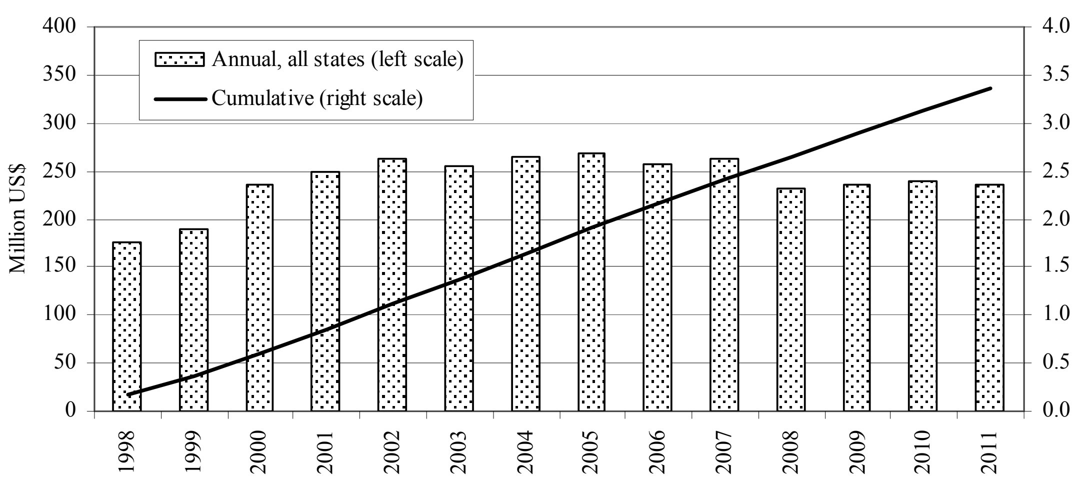


Figure 3.21: Aggregation Annual and Cumulative State Funding



Source: Bolinger et al. 2001.

Table 3.21: Renewable Energy Funding Levels and Program Duration

State	Approximate Annual Funding ($ Million)	$ Per-Capita Annual Funding	$ Per-MWh Funding	Funding Duration
CA	135	4.0	0.58	1998 - 2011
CT	15 → 30	4.4	0.50	2000 - indefinite
DE	1 (maximum)	1.3	0.09	10/1999- indefinite
IL	5	0.4	0.04	1998 - 2007
MA	30→20	4.7	0.59	1998 - indefinite
MT	2	2.2	0.20	1999 - 2005
NJ	30	3.6	0.43	2001 – 2008
NM	4	2.2	0.22	2007 – indefinite
NY	6 → 14	0.7	0.11	7/1998 – 6/2006
OH	15 → 5 (portion of)	1.3	0.09	2001 – 2010
OR	8.6	2.5	0.17	3/2002 – 2/2011
PA	10.8	0.9	0.08	1999 – indefinite
RI	2	1.9	0.28	1997 – 2006
WI	1 → 4.8	0.9	0.07	4/1999 - indefinite

Note: Annual and per-MWh funding are based on funds expected in 2001.
Source: Bolinger, M., R. Wiser, L. Milford, M. Stoddard, and K. Porter. Clean Energy Funds: An Overview of State Support for Renewable Energy, Lawrence Berkeley Laboratory, April 2001.

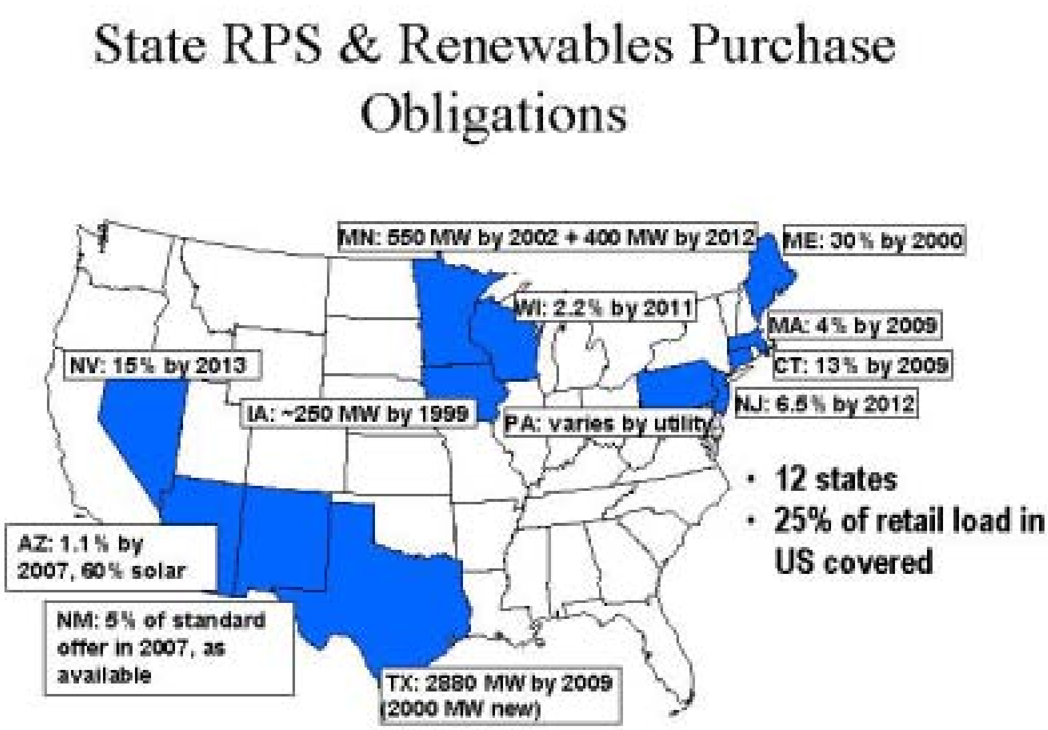
Table 3.22: State SBC Funding of Large-Scale Renewable Projects

State	Form of Funding Distribution	Level of Funding ($ Million)	Results[1]	Discounted cents/kWh Incentive over Five Years[2]
CA	Five-year production incentive	162 40 40	543 MW (assorted) 471 MW (assorted) 300 MW (assorted)	1.20 0.59 0.75
IL	Grant	0.55 1 0.352 0.55	3 MW landfill gas 3 MW hydro 1.2 MW hydro 15 MW landfill gas	0.57 1.86 1.63 0.11
MT	Three-year production incentive	1.5	3 MW wind	3.63
NY	Grants with performance guarantees	9 4	51.5 MW wind 6.6 MW wind	1.95 6.75
PA	Grant/ production incentive	6	67 MW wind	1.00

[1] Results are projected and are based on announced results of solicitations.
[2] Incentives have been normalized to their five-year production incentive equivalent using a 10% discount rate.
Source: Bolinger et al. 2001

3.3 - States with Renewable Portfolio Standards (RPS)

A Renewable Portfolio Standard (RPS) is a policy that obligates a retail electricity supplier to include renewable resources in its electricity generation portfolio. Retail suppliers can meet the obligation by constructing or owning eligible renewable resources or purchasing the power from eligible generators. To date, 10 states have adopted RPS policies. Most states have done so as part of electric industry restructuring, although Wisconsin has adopted an RPS without plans to open its market to competition.



Source: Union of Concerned Scientists and Lawrence Berkeley National Laboratory.

Table 3.3.1: State RPS Policies Established Under Restructuring

State	Purchase Requirement
Arizona	0.2% in 2001, rising by 0.2%/yr to 1% in 2005, and to 1.05% in 2006, then to 1.1% from 2007 to 2012. Competitive retail suppliers are exempt until 2004. Utility distribution companies may recover costs of the RPS through reallocating existing SBC accounts for DSM and partly through environmental portfolio surcharge.
Connecticut	Class I or II Technologies: 5.5% in 2000, 6% in 2005, 7% in 2009 and thereafter. Class I Technologies: 0.5% in 2000 + 0.25%/yr to 1% in 2002, 6% in 2009 and thereafter. Revised law in 1999 clarifies that standard is energy based, not capacity based and allows individual suppliers to petition PUC for delay of RPS targets of up to 2 years. PUC has denied at least one petition for delay. PUC has established that RPS shall not apply to standard offer service (slated to expire in 2004), but this decision is under appeal. Unclear if PUC exemption extends to default service.
Maine	30% of retail sales in 2000 and thereafter as condition of licensing. PUC will revisit RPS within 5 years after retail competition. PUC has proposed to eliminate RPS in favor of an SBC.
Massachu-setts	1% of sales to end-use customers from new renewables in 2003 or 1 year after any renewable is within 10% of average spot-market price, +0.5%/yr to 4% in 2009, and +1%/yr increase thereafter until date determined by Division of Energy Resources (DOER). RPS draft rules (October 2001) does not propose standard for existing renewables - DOER plans to monitor market and adopt standard if there is significant attrition of renewables.
Nevada	Original RPS in restructuring legislation replaced with new RPS legislation in summer 2001. Starts at 5% in 2003 and rises by 2% every two years until reaching 15% in 2013 and thereafter. At least 5% of the standard must come from solar (PV, thermal electric, or thermal).
New Jersey	Class I or II Technologies: 2.5% when BPU adopts interim standards with no sunset. Class I Technologies: 0.5% in 2001, 1% in 2006, +0.5%/yr to 4% in 2012.
New Mexico	Restructuring and original RPS delayed until 2007, interim RPS currently under consideration: 1% by 9/02, 3% by 9/03, 5% by 9/04. After 9/05, rule may be modified to apply to standard offer customers only, or may be withdrawn.
Pennsylvania	For PECO, West Penn, and PP&L, 20% of residential consumers served by competitive default provider: 2% in 2001, rising 0.5%/year. For GPU, 0.2% in 2001 for 20% of customers, 40% of customers in 2002, 60% in 2003, 80% in 2004 and thereafter.
Texas	Legislation establishes renewable energy capacity targets: 1280 MW by 2003 increasing to 2880 MW by 2009 (880 MW of which is existing generation). RPS rule translates capacity targets into percentage energy purchase requirements.
Wisconsin	0.5% by 2001, increasing to 2.2% by 2011 (0.6% can come from facilities installed before 1998).

Table 3.3.1: RPS Policies Established at the State Level Under Restructuring (continued)

State	Resource Eligibility	Credit Trading
AZ	2001—at least 50% solar electric—remainder from R&D, solar hot water, or other in-state landfill gas, wind and biomass. R&D investment can reduce RPS target by 10% 2002-2003—same as 2001 except R&D investments can reduce RPS target by up to 5% 2004-2012—at least 60% solar electric—remainder from solar hot water and in-state landfill gas, wind and biomass Out-of-state solar appears eligible; landfill gas, wind and biomass must be in-state	To be determined
CT	Class I: solar, wind, new sustainable biomass, landfill gas, and fuel cells; Class II: licensed hydro, MSW, other biomass. Out of state resources eligible.	Law allows suppliers to satisfy RPS by participating in credit trading program approved by the state, but state PUC has indicated it has no plans to establish a credit trading program; may allow private actors to develop trading system
ME	Fuel cells, tidal, solar, wind, geothermal, hydro, biomass, and MSW (under 100 MW); high efficiency cogeneration of any size; resource supply under this definition far exceeds RPS-driven demand. Out of state resources eligible; energy must be delivered to the ISO-NE control area and meet load in New England	PUC decided against credit trading to maintain consistency with regional disclosure tracking systems
MA	Solar, wind, ocean thermal, wave, or tidal, fuel cells using renewable fuels, landfill gas, waste-to-energy, hydro, and low-emission, advanced biomass; waste-to-energy and hydro cannot count toward new standard; new renewables defined as those that begin commercial operation or represent an increase in capacity at an existing facility after December 31, 1997; DOER can add technologies after hearings. Out of state resource eligible.	Credit trading would require subsequent legislative approval; DOER recommends against the creation of a Massachusetts-specific renewable energy credit market, because of the more comprehensive New England Generation Information System currently being developed
NV	Wind, solar (PV, solar thermal electric, solar thermal that offsets electric use), geothermal, and biomass energy resources that are naturally regenerated. 5% of each year's standard must come from solar. Unclear whether out of state resources are eligible.	Legislation allows credits, but PUC rule does not implement.
NJ	Class I: solar, PV, wind, fuel cells, geothermal, wave or tidal, and methane gas from landfills or a biomass facility, provided that the biomass is cultivated and harvested in a sustainable manner; Class II: hydro and resource recovery facilities in states with retail competition. Out of state resources eligible generally; Class II technologies must come from states open to retail competition	Electric suppliers may satisfy the RPS by participating in a renewable energy credit trading program approved by the Board of Public Utilities (BPU); interim RPS rule does not establish such a system
NM	Wind, solar, geothermal, biomass, hydro, and fuel cells. Out of state resources are eligible	Allowed, but not required or provided for in proposed rule
PA	Unspecified	Unspecified
TX	Solar, wind, geothermal, hydro, wave, tidal, biomass, biomass-based waste products, landfill gas. Out of state resources not eligible unless dedicated transmission line into the state	Texas is first state to establish credit trading program; ERCOT ISO selected as the program administrator
WI	Wind, solar, biomass, geothermal, tidal, fuel cells that use renewable fuel, hydro under 60 MW; eligibility may be expanded by PUC. Out of state resources are eligible	Legislation allows renewable purchases to be satisfied through the purchase of renewable energy credits; credits awarded for renewable energy generation over RPS requirement

Table 3.3.1: RPS Policies Established at the State Level Under Restructuring (continued)

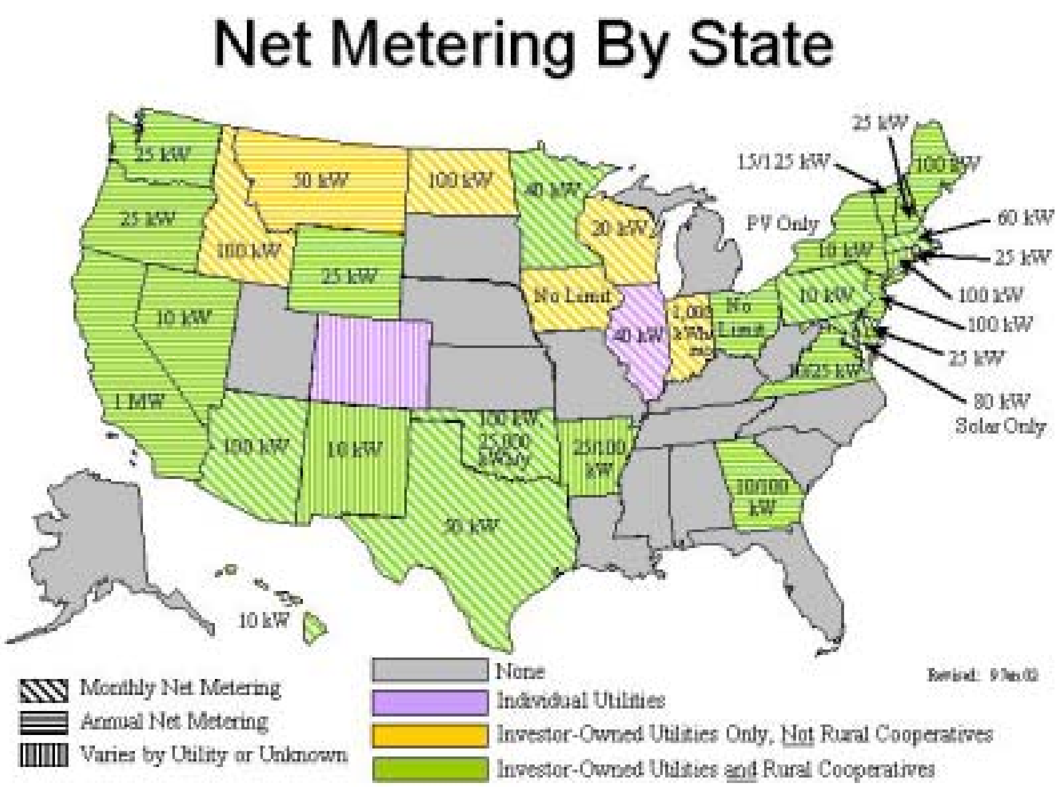
State	Penalties	Status
AZ	30 cents/kWh starting in 2004; proceeds go to solar electric fund to finance solar facilities for schools, cities, counties or state agencies	Commission order in April 2000; rulemaking later in 2000; comprehensive review of policy in 2003 to determine RPS status and level from 2004 onward
CT	Must meet RPS to be licensed; flexible penalties for failing to comply with license conditions include license revocation or suspension, a prohibition from accepting new customers, or civil penalties	Restructuring legislation in 1998; licensing regulations in 1998 established certain RPS provisions; revisions to law in 1999; RPS begins July 1, 2000
ME	Variety of possible sanctions at discretion of Commission including license revocation, monetary penalties, and other appropriate penalties; allows voluntary payment into renewables R&D fund to avoid license revocation	Restructuring legislation in 1997; PUC worked out design details in 1998; revisions to RPS law in May 1999; RPS took effect March 1, 2000; PUC considering proposing legislation to drop RPS in favor of SBC
MA	DOER draft rule requires non-complying retailers to make up any shortfall in the first quarter of the following year and submit a compliance plan, or else face public notice of non-compliance and possible suspension or revocation of license.	Restructuring legislation in 1997; DOER released draft rule in October 2001, seeking public comment; new RPS begins in 2003
NV	Administrative fine that at least equals the cost differential between “just and reasonable” renewable electricity and system power. Exemptions from fines granted if not enough renewable power available at just and reasonable prices.	SB372 signed 06/01, PUC rules initially adopted 12/01, but now re-working to remove soft cap
NJ	Interim RPS rule requires non-complying retailers to make up any shortfall in the following year, or else face financial penalties and/or license revocation or suspension	Restructuring legislation in 1999; draft RPS rule in late 1999; interim rule adopted in 2001, final rule due 18 months later; RPS begins in 4Q 2001
NM	Describes how to request exemption or variance; does not address consequences of exemption or variance being denied	Draft rule from PRC staff currently in rulemaking phase, public comments due Jan-02, seeking to implement in May-02
PA	Unspecified	Legislation in 1996; individual utility settlements in 1998
TX	Penalty for noncompliance is the lesser of 5 cents/kWh or 200% of the average market value of renewable energy credits; under certain circumstances, penalty may not be assessed	Restructuring legislation in 1999; final RPS rule complete in 12/99; credit trading protocol being designed and implemented; RPS begins in 2002, with early compliance beginning in mid 2001
WI	Penalty of $5,000 - $500,000 is allowed in legislation	RPS legislation established as part of state budget within a wholesale electricity reform measure in late 1999; final regulation adopted April 2001; utilities contracting for renewable power

Source: Wiser, R. and M. Bolinger, Lawrence Berkeley National Laboratory and K. Porter, National Renewable Energy Laboratory. Updated January 2002.

3.4 - States with Net Metering Policies

Net metering allows customers with generating facilities to turn their electric meters backward when their systems are producing energy in excess of the their on-site demand. In this way, net metering enables customers to use their own generation to offset their consumption over a billing period. This offset means that customers receive retail prices for the excess electricity they generate. Without net metering, a second meter is usually installed to measure the electricity that flows back to the provider, with the provider purchasing the power at a rate much lower than the retail rate.

Figure 3.41 Net Metering Policies by State



Source: J. Green, National Renewable Energy Laboratory, January 2002.
http://www.eren.doe.gov/greenpower/netmetering/index.shtml

Table 3.41 Summary of State Net Metering Policies

State	Allowable Technology and Size	Allowable Customers	Statewide Limit	Treatment of Net Excess Generation (NEG)	Enacted	Scope of Program
Arizona	Renewables and cogeneration ≤100 kW	All customer classes	None	NEG purchased at avoided cost	1981	All IOUs and RECs
Arkansas	Renewables, fuel cells and microturbines ≤25 kW residential ≤100 kW commercial	All customer classes	None	TBD by Public Service Commission	2001	All utilities
California	Solar and wind ≤1000 kW	All customer classes	None	Annual NEG granted to utilities	2001/ 1995	All utilities
Colorado	Wind and PV 3 kW, 10 kW	Varies	NA	Varies	1997	Four Colorado utilities
Connecticut	Renewables and fuel cells ≤100 kW	Residential	None	Not specified	1990, updated 1998	All IOUs, No REC in state.
Delaware	Renewables ≤25 kW	All customer classes	None	Not specified	1999	All utilities
Georgia	Solar, wind, fuel cells ≤10 kW residential ≤100 kW commercial	Residential and commercial	0.2% of annual peak demand	Monthly NEG or total generation purchased at avoided cost or higher rate if green priced	2001	All utilities
Hawaii	Solar, wind, biomass, hydro ≤10 kW	Residential and small commercial	0.5% of annual peak demand	Monthly NEG granted to utilities	2001	All utilities
Idaho	All technologies ≤100 kW	Residential and small commercial (Idaho Power only)	None	Monthly NEG purchased at avoided cost	1980	IOUs only, RECs are not rate-regulated
Illinois	Solar and wind ≤40 kW	All customer classes; ComEd only	0.1% of annual peak demand	NEG purchased at avoided cost	2000	Commonwealth Edison
Indiana	Renewables and cogeneration ≤1,000 kWh/month	All customer classes	None	Monthly NEG granted to utilities	1985	IOUs only, RECs are not rate-regulated
Iowa	Renewables and cogeneration (No limit per system)	All customer classes	105 MW	Monthly NEG purchased at avoided cost	1993	IOUs only, RECs are not rate-regulated [2]

State	Allowable Technology and Size	Allowable Customers	Statewide Limit	Treatment of Net Excess Generation (NEG)	Enacted	Scope of Program
Maine	Renewables and fuel cells ≤100 kW	All customer classes	None	Annual NEG granted to utilities	1998	All utilities
Maryland	Solar only ≤80 kW	Residential and schools only	0.2% of 1998 peak	Monthly NEG granted to utilities	1997	All utilities
Massachu-setts	Qualifying facilities ≤60 kW	All customer classes	None	Monthly NEG purchased at avoided cost	1997	All utilities
Minnesota	Qualifying facilities ≤40 kW	All customer classes	None	NEG purchased at utility average retail energy rate	1983	All utilities
Montana	Solar, wind and hydro ≤50 kW	All customer classes	None	Annual NEG granted to utilities at the end of each calendar year.	1999	IOUs only
Nevada	Solar and Wind ≤10 kW	All customer classes	First 100 customers for each utility	Monthly or annual NEG granted to utilities	1997	All utilities
New Hampshire	Solar, wind and hydro ≤25 kW	All customers classes	0.05% of utility's annual peak	NEG credited to next month	1998	All utilities
New Jersey	PV and wind ≤100 kW	Residential and small commercial	0.1% of peak or $2M annual financial impact	Annualized NEG purchased at avoided cost	1999	All utilities
New Mexico	Renewables and cogeneration	All customer classes	None	NEG credited to next month, or monthly NEG purchased at avoided cost (utility choice)	1999	All utilities
New York	Solar only ≤10 kW	Residential only	0.1% 1996 peak demand	Annualized NEG purchased at avoided cost	1997	All utilities
North Dakota	Renewables and cogeneration ≤100 kW	All customer classes	None	Monthly NEG purchased at avoided cost	1991	IOUs only, RECs are not rate-regulated
Ohio	Renewables, microturbines, and fuel cells (no limit per system)	All customer classes	1.0% of aggregate customer demand	NEG credited to next month	1999	All utilities
Oklahoma	Renewables and cogeneration ≤100 kW and ≤25,000	All customer classes	None	Monthly NEG granted to utility	1988	All utilities

State	Allowable Technology and Size	Allowable Customers	Statewide Limit	Treatment of Net Excess Generation (NEG)	Enacted	Scope of Program
	kWh/year					
Oregon	Solar, wind, fuel cell and hydro ≤25 kW	All customer classes	0.5% of peak demand	Annual NEG granted to low-income programs, credited to customer, or other use determined by Commission	1999	All utilities
Pennsyl-vania	Renewables and fuel cells ≤10 kW	Residential	None	Monthly NEG granted to utility	1998	All utilities
Rhode Island	Renewables and fuel cells ≤25 kW	All customer classes	1 MW for Narragansett Electric Company	Annual NEG granted to utilities	1998	Narragansett Electric Company
Texas	Renewables only ≤50 kW	All customer classes	None	Monthly NEG purchased at avoided cost	1986	All IOUs and RECs
Vermont	PV, wind, fuel cells ≤15 kW Farm biogas ≤125 kW	Residential, commercial and agricultural	1% of 1996 peak	Annual NEG granted to utilities	1998	All utilities
Virginia	Solar, wind and hydro Residential ≤10 kW Non-residential ≤25 kW	All customer classes	0.1% of peak of previous year	Annual NEG granted to utilities (power purchase agreement is allowed)	1999	All utilities
Washington	Solar, wind, fuel cells and hydro ≤25 kW	All customer classes	0.1% of 1996 peak demand	Annual NEG granted to utility	1998	All utilities
Wisconsin	All technologies ≤20 kW	All retail customers	None	Monthly NEG purchased at retail rate for renewables, avoided cost for non-renewables	1993	IOUs only, RECs are not rate-regulated
Wyoming	Solar, wind and hydro ≤ 25 kW	All customer classes	None	Annual NEG purchased at avoided cost	2001	All IOUs and RECs

Source: National Renewable Energy Lab and Tom Starrs of Kelso Starrs and Associates. January 2002. http://www.eren.doe.gov/greenpower/netmetering/index.shtml

Notes:

IOU — Investor-owned utility
GandT — Generation and transmission cooperatives
REC — Rural electric cooperative

[1] For information, see the Database of Statet Incentive for Renewable Energy (http://www.dcs.ncsu.edu/solar/dsire/dsire.cfm).

The original format for this table is taken from: Thomas J. Starrs (September 1996). *Net Metering: New Opportunities for Home Power.* Renewable Energy Policy Project, Issue Brief, No. 2. College Park, MD: University of Maryland

3.5 - States with Environmental Disclosure Policies

As electricity markets open to competition, retail consumers are increasingly gaining the ability to choose their electricity suppliers. With this choice comes the need for consumers to have access to information about the price, source, and environmental characteristics of their electricity. For green power marketers in particular, it is important that consumers understand the environmental implications of their energy consumption decisions. To date, more than 20 states have *environmental disclosure* policies in place, requiring electricity suppliers to provide information on fuel sources and, in some cases, emissions associated with electricity generation. Although most of these policies have been adopted in states with retail competition, a handful of states with no plans to implement restructuring have required environmental disclosure. Summaries of state environmental disclosure policies are provided below under the categories full, partial, or proposed. The term *partial disclosure requirements* refers to policies that are not mandatory, do not apply to all retail electricity suppliers, or do not result in direct disclosure to consumers.

Table 3.51 Environmental Disclosure Requirements by State, October 2001

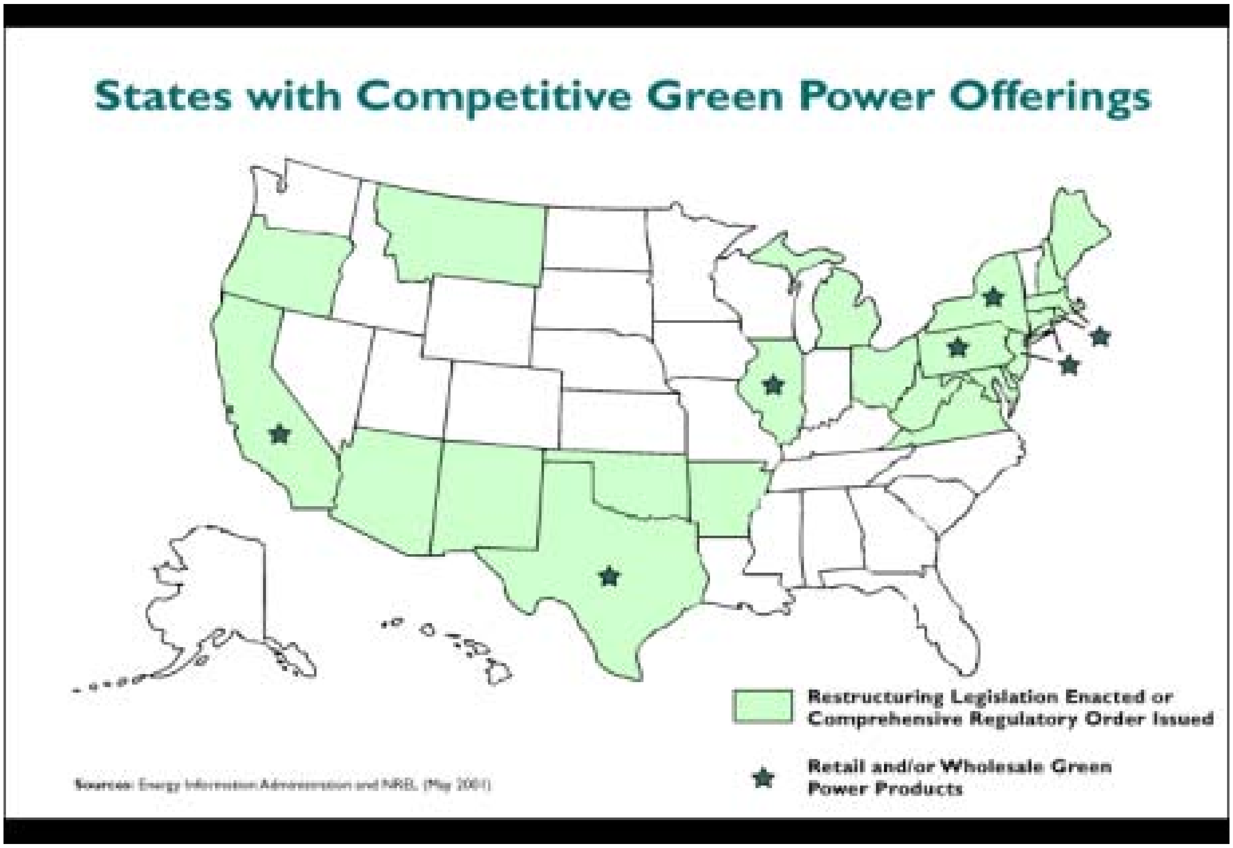
State	Disclosure Requirement	Scope	Frequency	Distribution	Effective Date	Authority
Arkansas	Standards to be set for disclosure of environmental impacts	Electric service providers	TBD	TBD	TBD	Legislature
California	Fuel mix required in standard format.	Electric service providers	Quarterly	Bill insert, offers, and written promotional materials (except ads)	1999	Legislature
Colorado	Fuel mix. Standard format is suggested.	Investor owned utilities with load >100MW	Twice annually	Bill insert or mailing	1999	Public Utility Commission
Connecticut	Fuel mix and air emissions	Electric distribution companies	TBD	TBD	TBD	Legislature
Delaware	Fuel mix	Electric suppliers	Quarterly	Bill insert or mailing, offers, marketing materials	1999	Public Service Commission
Florida	Fuel mix	Investor-owned utilities	Quarterly	On bill or bill insert	1999	Public Service Commission
Illinois	Fuel mix and CO_2; NOx; SO_2; high-level and low-level nuclear waste emissions in standard format.	Electric utilities and alternative retail suppliers	Quarterly	Bill insert	1998	Legislature
Maine	Fuel mix and CO_2 NO_x; SO_2 emissions in format similar to sample	Electric service providers (Residential and small commercial customers only.)	Quarterly	Bill insert or mailing and prior to initiation of service.	1999	Public Utilities Commission
Maryland	Fuel mix and CO_2; NO_x; SO_2 emissions in standard format	Electric suppliers	Twice annually	Bill insert or mailing and with contracts	2000	Legislature
Massachusetts	Fuel mix and CO_2; NO_x; SO_2 emissions in standard format	Competitive suppliers	Quarterly	Bill insert and prior to initiation of service.	1998	Dept. of Telecomm-unications and Energy
Michigan	Fuel mix and SO_2; CO_2; NO_x; high-level nuclear	Electric utilities and alternative	Twice annually	Bills and on Commission	(2002)	Legislature

State	Disclosure Requirement	Scope	Frequency	Distribution	Effective Date	Authority
	waste emissions in standard format	electric providers		web site		
Minnesota	Fuel mix, air pollutant emissions, and nuclear waste emissions in standard brochure	Rate regulated electric utilities	Twice annually	Web, phone referral on bill, full info on bill insert	(2002)	Public Utilities Commission
New Jersey	Fuel mix, energy efficiency, and CO_2; SO_2; NO_x emissions in standard format	All electric suppliers	Twice annually	Mailings, direct mail marketing, solicitations, contracts	1999	Legislature
New Mexico	Fuel mix and associated emissions, standard format required under proposed rules	Competitive electric suppliers	TBD, proposed annually	TBD	TBD	Legislature
New York	Fuel mix and CO_2; SO_2; NO_x emissions in standard format	Load serving entities	Twice annually	Bill insert and prior to offers	(2002)	Public Service Commission
Ohio	Fuel mix, CO_2; SO_2; NO_x emissions and high-level and low-level radioactive waste in standard format	Retail electric service providers	Annually , plus quarterly comparisons of actual and projected	Bill insert or mailing, and contracts	2001	Legislature
Oregon	Fuel mix and CO_2; SO_2; NO_x; spent nuclear fuel emissions in standard format	Electric service providers	Quarterly	On bill or insert, marketing materials, contracts, URL on bill	2000	Legislature
Texas	Fuel mix and CO_2; SO_2; NO_x; Particulates; Nuclear waste emissions in standard format	Retail electric providers	Twice annually	Bill insert or mailing, solicitations, Commission web site	(2002)	Legislature
Washington	Fuel mix in standard format	Retail suppliers	Twice annually (plus two referrals)	Bill insert or mailing, solicitations	2001	Legislature
Arizona	Fuel mix and emissions to extent reasonably known	Electric suppliers including default suppliers	Upon request and written marketing materials	Upon request	2000	Arizona Corporation Commission
District of Columbia	Fuel mix	Retail electricity suppliers	Twice annually to Commission	Supplied only to the Commission	2001	Legislature
Pennsylvania	Fuel mix and energy efficiency	Electric generation supplier	Upon request	Supply to Commission annually	1998	Public Utility Commission
Virginia	Fuel mix and emissions to the extent feasible	Competitive service providers; CSP's making claim-based sales	Annually to extent feasible	"Reported to customers."	(2002)	Virginia State Corporation Commission
Montana	Fuel mix and CO_2; SO_2; NO_x, spent nuclear waste, hydro	Retail electricity suppliers	Twice annually	Product offers, contracts, ads	TBD	Dept. of Public Service Regulation
West Virginia	Fuel mix and CO_2; SO_2; NO_x and high-level and low-level nuclear waste	Retail electricity suppliers including default suppliers	Supplied to Commission quarterly	Solicitations Posted on company web site	TBD	Public Service Commission

Source: L. Bird and D. Lackaff, National Renewable Energy Laboratory, October 2001.
http://www.eren.doe.gov/greenpower/disclosetxt.shtml

3.6 - States with Competitive Green Power Offerings

Green power marketing refers to selling green power in the competitive marketplace, in which multiple suppliers and service offerings exist. Electricity markets are now open to full competition in a number of states, while others are phasing in competition, allowing some customers to choose their electricity supplier. To date, competitive marketers have offered green power to retail or wholesale customers in California, Illinois, Pennsylvania, New Jersey, New York, Texas, and several New England states.



Source: B. Swezey and L. Bird 2000. Updated December 2001.

Table 3.62: New Renewables Capacity Added from Green Power Marketing (in kW)

Source	Added	%	Planned	%
Wind	423,380	*98.4*	277,200	*84.7*
Photovoltaics	337	*0.1*	295	*0.1*
Landfill Gas	1,600	*0.4*	0	*0.0*
Geothermal	5,000	*1.2*	49,900	*15.2*
Total	**430,317**	***100.0***	**327,395**	***100.0***

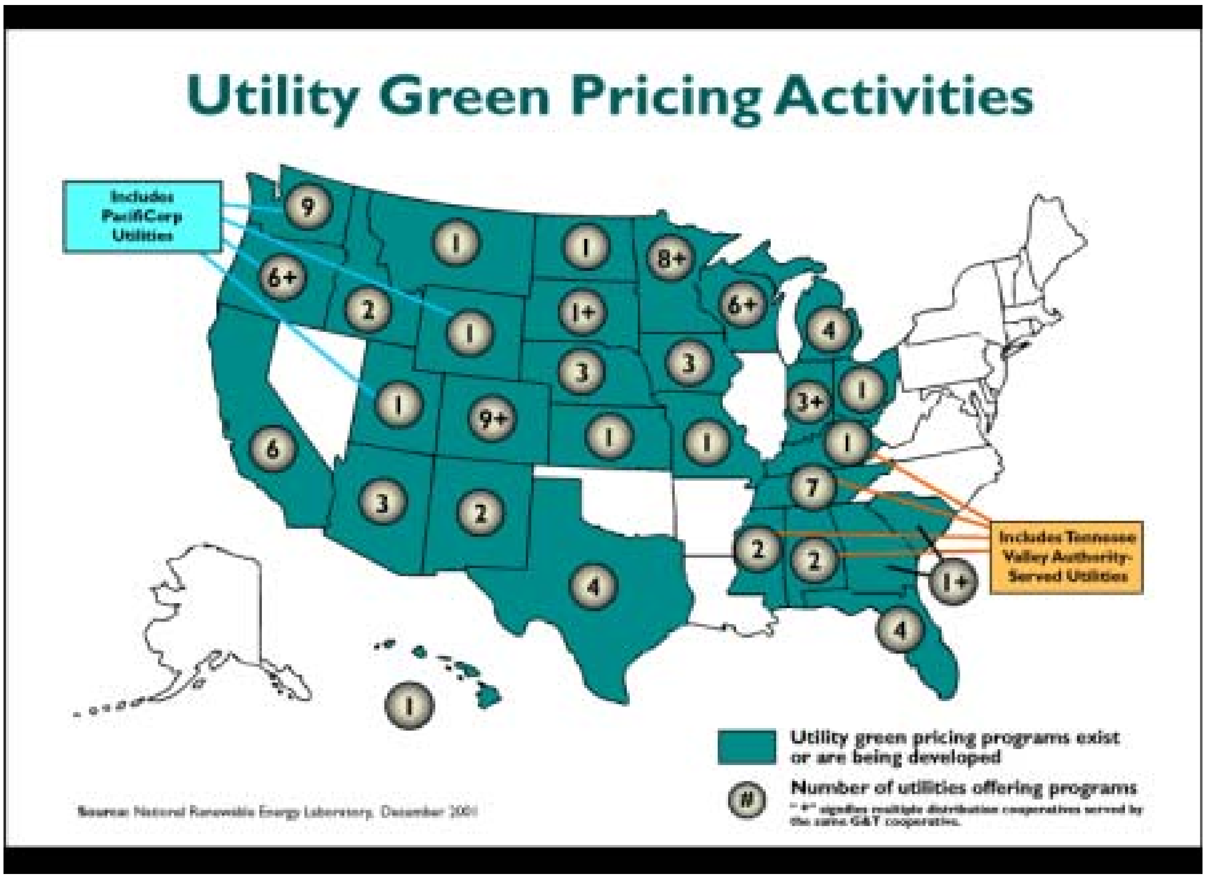
Table 3.61 Residential Green Power Product Offerings (as of April 2001)					
Company	**Product Name**	**Price Premium (¢/kWh)**	**Monthly Fee**	**Resource Mix**	**Green-e Certified**
Connecticut[1]					
CT Energy Coop	EcoWatt	1.0	Initial $30	67% small hydro, 27% landfill gas, 6% new wind	✔
Green Mountain Energy Company	Green Mountain Energy	0.5		5% wind, 45% biomass and small hydro	✔
Sun Power Electric	Regen	3.6		100% renewable energy blocks, solar and landfill gas	
Massachusetts					
Sun Power Electric/ Mass Energy Consumers Alliance	Regen	3.6		100% renewable energy blocks, solar and landfill gas	
New Jersey[3]					
Green Mountain Energy Company	Ecosmart Enviroblend	-1.35-0.45	$3.95/ mo. $3.95/ mo.	1% new renewables, 50% large hydro 45% small hydro/landfill gas, 50% large hydro 5% new	 ✔
Pennsylvania[4]					
ElectricAmerica	50% Hydro	-0.02		50% large hydro	
Energy Cooperative of Pennsylvania	Eco Choice 100	0.7	$5/year	100% landfill gas, 5% new	✔
Community Energy/PECO Energy	New Wind Energy	2.5		100% wind energy kWh-blocks	
Green Mountain Energy Company	Eco Smart Enviro Blend Nature's Choice	-0.15 0.79 1.35	$3.95 $3.95 $3.95	1% new wind, 99% natural gas and hydro 45% small hydro and landfill gas, 5% new 95% small hydro/landfill gas, 5% new	✔ ✔
Mack Services Group	100% Renewable	1.86		100% landfill gas, 5% new	✔
Rhode Island					
Sun Power Electric	Regen	3.6		100% renewable energy blocks, solar and landfill gas	
Texas Retail Competition Pilot					
Green Mountain Energy Company	100% Wind Power	N/A	$4.95	100% wind	

[1] Product prices are for Connecticut Light & Power service territory.
[2] Product prices are for Central Maine Power service territory.
[3] Product prices are for Conectiv service territory.
[4] Product prices are for PECO service territory.

Source: B. Swezey and L. Bird, 2000. Updated April 2001.

3.7 - States with Utility Green Pricing Programs

Green pricing is an optional utility service that allows customers an opportunity to support a greater level of utility company investment in renewable energy technologies. Participating customers pay a premium on their electric bill to cover the extra cost of the renewable energy. Many utilities are offering green pricing to build customer loyalty and expand business lines and expertise prior to electric market competition. To date, more than 90 utilities in 30 states have either implemented or announced plans to offer a green pricing option.



Source: B. Swezey and L. Bird 2000. Updated December 2001.

Table 3.72 New Renewables Capacity Added from Green Pricing Programs (in kW)

Source	Added	%	Planned	%
Wind	180,185	*82.7*	70,740	*62.5*
Solar	3,891	*1.8*	1,570	*1.4*
Biomass	27,390	*12.6*	38,960	*34.4*
Small Hydro	6,500	*3.0*	1,953	*1.7*
Total	**217,966**		**113,223**	

Table 3.73 - Utility Green Pricing Programs, December 2001

	Utility Name	Program Name	Resource Type	Size	Start Date	Premium
AL	Alabama Power (Southern Company)	EarthCents Solar	central PV	joint 1 MW	2000	$6.00/100 watts
AL	Huntsville Utilities (TVA)	Green Power Switch	wind, landfill gas, solar	joint 8.7 MW	2000	2.67¢/ kWh
AZ	Arizona Public Service	Solar Partners Program	central PV	1 MW	1996	$2.64/ 15kWh
AZ	Salt River Project	Earthwise Energy	central PV, landfill gas, small hydro	4.4 MW	1998/ 2001	3.0¢/kWh
AZ	Tucson Electric	GreenWatts	landfill gas, PV	6 kW	2000	7.5-10¢/ kWh
CA	City of Alameda	Clean Future Fund	various, electric vehicles	--	1999	1.0¢/kWh
CA	City of Palo Alto Utilities	Green Resources	biomass, geothermal	N/A	2000	3.0¢/kWh
CA	Los Angeles Dept. of Water and Power	Green Power for a Green LA	wind, landfill gas	25 MW	1999	3.0¢/kWh
CA	Roseville Electric	Green Energy Program	geothermal, PV	9 kW	2000	1.0¢/kWh
CA	Sacramento Municipal Utility District	Greenergy	landfill gas, PV	8.3 MW	1997	1.0¢/kWh
CA	Sacramento Municipal Utility District	PV Pioneers I/II	PV	1.9 MW	1993; 1998	$4/month
CA	Turlock Irrigation District	Green Valley Energy	existing small hydro	--	1999	~1.0¢/kWh
CO	Colorado Springs Utilities	Green Power	wind	1 MW	1997	3.0¢/kWh
CO	Holy Cross Energy	Wind Power Pioneers	wind	3.0 MW	1997	2.5¢/kWh
CO	Platte River Power Authority: Estes Park, Fort Collins, Longmont, Loveland	Wind Energy Program	wind	5.9 MW	1999	2.5¢/kWh
CO	Public Service Company of Colorado	WindSource	wind	56 MW	1997	2.5¢/kWh
CO	Public Service Company of Colorado	Renewable Energy Trust	PV	100 kW	1993	Contribution
CO	Tri-State Generation & Transmission	Renewable Resource Power Service	wind, landfill gas	planned 2.66 MW	1999	2.5¢/kWh
CO	Yampa Valley Electric Association	Green Power	wind	450 kW	1999	3.0¢/kWh
FL	City of Tallahassee	TBD	TBD	TBD	TBD	TBD
FL	Florida Power & Light	TBD	TBD	TBD	1997	TBD
FL	Gainesville Regional Utilities	Solar for Schools Program	rooftop PV	planned 32 kW	1993/ 1997	$3.00/50 watts
FL	Gainesville Regional Utilities	TBD	landfill gas	TBD	TBD	TBD
FL	Gulf Power Company (Southern Company)	Solar for Schools; EarthCents Solar	PV in schools; central PV	10 kW; joint 1 MW	1996; 1999	Contribution; $6.00/ 100 watts
FL	New Smyrna Beach	Green Power	local PV projects	--	1999	Contribution
FL	Tampa Electric Company (TECO)	Smart Source	PV, biomass (co-firing)	3 kW	2000	10.0¢/kWh
GA	Electric Membership Corporation	Green Power EMC	landfill gas	13 MW	2001	TBD
HI	Hawaiian Electric	Sun Power for Schools	PV in schools	22 kW	1996	Contribution
ID	Idaho Power	Green Power Program	various	TBD	2001	Contribution

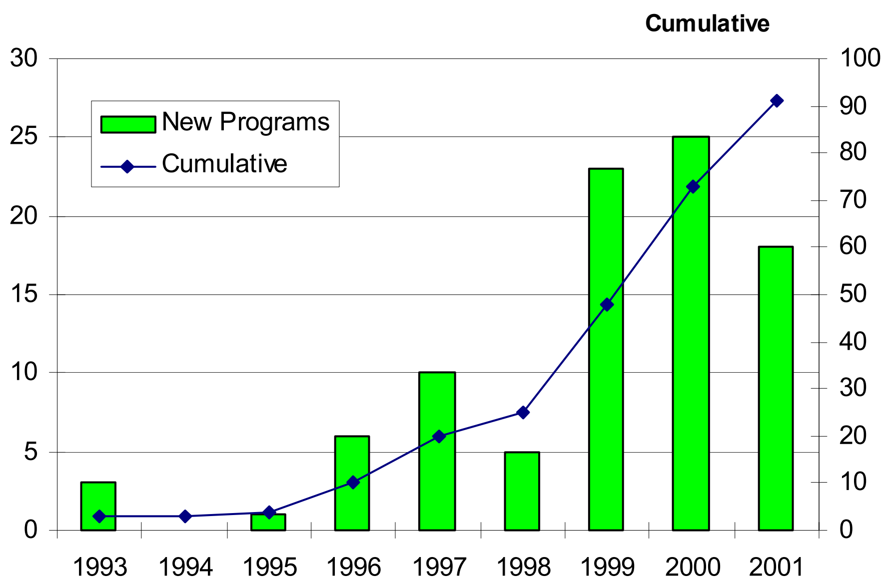
	Utility Name	Program Name	Resource Type	Size	Start Date	Premium
ID	Avista Utilities	TBD	wind	TBD	2002	1.8¢/kWh
IA	Alliant Energy	Second Nature	landfill gas, wind	4.6 MW	2000	2.0¢/kWh
IA	Cedar Falls Utilities	Wind Energy Electric Project	wind	1.5 MW	1999	Contribution
IA	Waverly Light & Power	Iowa Energy Tags	wind	planned 1.8 MW	2001	2.0¢/kWh
IN	PSI Energy/Cinergy	Green Power Rider	wind, solar, landfill gas, digester gas	TBD	2001	Contribution
IN	Indianapolis Power & Light	Elect PlanSM Green Power Program	geothermal	0.5 aMW	1998	0.9¢/kWh
IN	Wabash Valley Power Assoc.	Enviro Watts	landfill gas	7.5 MW	2000	0.5-1.0¢/kWh
KS	Western Resources	Wind Power	wind	1.5 MW	1999	5.0¢/kWh
KY	Bowling Green Municipal Utilities (TVA)	Green Power Switch	wind, landfill gas, solar	joint 8.7 MW	2000	2.67¢/kWh
MI	Consumers Energy	Green Power Pilot Program	wind, various	up to 50 MW	2001	3.2¢/kWh
MI	Detroit Edison	Solar Currents	central PV	55 kW	1996	$6.59/100 watts
MI	Lansing Board of Water and Light	GreenWise Electric Power	landfill gas, small hydro	1 aMW	2001	3.0¢/kWh
MI	Traverse City Light and Power	Green Rate	wind	600 kW	1996	1.58¢/kWh
MN	Dakota Electric Association	Wellspring Renewable Wind Energy Program	wind	660 kW	1997	1.28¢/kWh
MN	East River Electric Power Cooperative	Prairie Winds	wind	2.6 MW	2000	3.0¢/kWh
MN	Great River Energy (excluding Dakota)	Wellspring Renewable Wind Energy Program	wind	2 MW	1997	1.28-2.0¢/kWh
MN	Minnesota Power	Wind Sense	wind	1 MW	2000	2.5¢/kWh
MN	Minnkota Power Cooperative	Infinity Wind Energy	wind	900 kW	1999	3.0¢/kWh
MN	Moorhead Public Service	Capture the Wind	wind	750 kW	1998	1.5¢/kWh
MN	Otter Tail Power	Tailwinds	wind	900 kW	2001	2.6¢/kWh
MN	Southern Minnesota Municipal Power Agency	Wind Power	wind	900 kW	2000	3.0¢/kWh
MS	City of Oxford, North East Mississippi Electric Power Asssoc. (TVA)	Green Power Switch	wind, landfill gas, solar	joint 8.7 MW	2000	2.67¢/kWh
MO	City Utilities of Springfield	WindCurrent	wind	purchase from Western	2000	5.0¢/kWh
MT	Flathead Electric Cooperative	Green Power	wind, small hydro	1.0 aMW	1999	2.0¢/kWh
ND	Minnkota Power Cooperative	Infinity Wind Energy	wind	900 kW	1999	3.0¢/kWh
NE	Lincoln Electric System	LES Renewable Energy Program	wind	1.32 MW	1998	4.3¢/kWh

	Utility Name	Program Name	Resource Type	Size	Start Date	Premium
NE	Nebraska Public Power District	Prairie Power Program	TBD	TBD	1999	Contribution
NE	Omaha Public Power District	Energy Choices Program	landfill gas, wind	3.9 MW	2001	3.0¢/kWh
NM	Kit Carson Electric Cooperative (Tri-State)	Renewable Resource Power Service	wind, landfill gas	planned 2.66 MW	2001	2.5¢/kWh
NM	Southwestern Public Service	WindSource	wind	660 kW	1999	3.0¢/kWh
OH	City of Bowling Green	Green Power	small hydro, PV	2 kW	1999	1.38¢/kWh
OR	City of Ashland	Ashland Solar Pioneer Program	PV	30 kW	1999	$4/month
OR	Eugene Water & Electric Board	EWEB Wind Power	wind	6.5 MW	1999	2.43¢/kWh
OR	Midstate Electric Cooperative	Environmentally Preferred Power	wind, small hydro	0.2 aMW	1999	2.5¢/kWh
OR	Pacific Northwest Generating Cooperative	Green Power	landfill gas	1.1 MW	1998	1.8-2.0¢/kWh
OR	Pacific Power (Pacificorp)	Blue Sky	wind	joint 3 MW	2000	2.95¢/kWh
OR	Portland General Electric Company	Salmon Friendly and Clean Wind Power	wind, low-impact hydro	planned 14 MW	2000	3.5¢/kWh
SC	Santee Cooper	Green Power Program	landfill gas	2.2 MW	2001	3.0¢/kWh
SD	East River Electric Power Cooperative	Prairie Winds	wind	2.6 MW	2000	3.0¢/kWh
TN	Chattanooga, Gibson Electric, Knoxville, Nashville, Newport, Powell Valley, Servier County (TVA)	Green Power Switch	landfill gas, solar, wind	joint 8.7 MW	2000	2.67¢/kWh
TX	Austin Energy	GreenChoice	wind, landfill gas, solar	76.7 MW	2000/ 1997	0.17¢/kWh
TX	City Public Service of San Antonio	Windtricity	wind	25 MW	2000	4.0¢/kWh
TX	El Paso Electric	Renewable Energy Tariff	wind	1.32 MW	2001	1.92¢/kWh
TX	Texas New Mexico Power Company	Wind Power	wind	2.6 MW	2001	1.0¢/kWh
UT	Utah Power (Pacificorp)	Blue Sky	wind	joint 3 MW	2000	2.95¢/kWh
WA	Avista Utilities	TBD	wind	TBD	2002	1.8¢/kWh
WA	Benton County Public Utility District	Green Power Program	landfill gas, wind	1 MW	1999	Contribution
WA	Chelan County PUD	Sustainable Natural Alternative Power	PV, wind	10 kW	2001	Contribution
WA	Clark Public Utilities	Green Lights	PV, wind	TBD	2002	1.5¢/kWh
WA	Orcas Power & Light	Green Power	small hydro, wind, PV	0.5 aMW	1999	3.5¢/kWh
WA	Puget Sound Energy	Green Power	wind, various	TBD	2002	2.0¢/kWh

	Utility Name	Program Name	Resource Type	Size	Start Date	Premium
WA	Pacific Power (Pacificorp)	Blue Sky	wind	joint 3 MW	2000	2.95¢/kWh
WA	Seattle City Light	TBD	solar, wind, biomass	TBD	2002	Contribution
WA	Snohomish County PUD	Planet Power	wind	0.5aMW	2002	2.0¢/kWh
WA	Tacoma Power	Evergreen Options	small hydro, wind	1 aMW	2000	Contribution
WI	Alliant Energy	Second Nature	wind, landfill gas	4.6 MW	2000	2.0¢/kWh
WI	Dairyland Power Cooperative	Evergreen Renewable Energy Program	wind	660 kW	1997	3.0¢/kWh
WI	Madison Gas & Electric	Wind Power Program	wind	8.22 MW	1999	3.3¢/kWh
WI	Wisconsin Electric Power Company	Energy for Tomorrow	wood, landfill gas, hydro, wind	9.8 MW	1996	2.0¢/kWh
WI	Wisconsin Public Power Inc.	Renewable Energy Program	small hydro, wind, digester gas	6.0 MW	2001	2.0¢/kWh
WI	Wisconsin Public Service	Solar Wise for Schools	PV installations in schools	60 kW	1996	Contribution
WY	Pacific Power (Pacificorp)	Blue Sky	wind	joint 3 MW	2000	2.95¢/kWh

Source: B. Swezey and L. Bird, National Renewable Energy Laboratory
http://www.eren.doe.gov/greenpower/summary.shtml

Figure 3.71 Growth Trend in Utility Green Pricing Programs



Source: B. Swezey and L. Bird 2000.

3.8 - State Incentive Programs

Many states have policies or programs in place to support renewable energy resources, such as tax incentives, industry recruitment incentives, or grant, loan, or rebate programs. The following table lists the incentives currently available by state.

Table 3.91 Financial Incentives for Renewable Energy Resources by State

State	Tax Incentives	Grants, Loans, Rebates	Other Incentives
AL	Wood burning space heating personal deduction	Geo-exchange loan program Renewable fuels grant program (biomass)	
AK		Power project revolving loan fund	
AZ	Qualifying wood stove tax deduction Solar and wind energy systems personal tax credit and sales tax exemption	Sun-Share PV buy-down program	Remote solar electric leasing program
AR	Advanced biofuels corporate tax credit	Alternative fuel vehicle conversion rebate	Emerging manufacturing facilities credit
CA	Solar and wind corporate and personal tax credit Solar personal tax deduction Solar system property tax exemption.	Solar water heater loan programs Various buy-downs Solar electric and geothermal rebates Various grants: electric vehicles, energy research, transportation Innovative building review program	PV Pioneer 2 Geothermal and PV leasing Solar water heating Energy technology export program
CO	Alternative fuel vehicle corporate and personal tax credits		
CT	Alternative fueled vehicle charging station and incremental cost credit Vehicles and equipment sales tax exemption Local option for property tax exemption	Housing investment fund	
DE			
DC			
FL	Solar energy equipment sales tax exemption	Various solar rebate programs	Solar water heater leasing
GA			
HI	Wind and solar corporate and personal tax credits	Solar water heating loan program	

State	Tax Incentives	Grants, Loans, Rebates	Other Incentives
	Alcohol fuels sales tax exemption	Various solar water heating rebate programs	
ID	Solar, wind and geothermal personal tax deduction	Low interest loans for renewable resources	
IL	Special property tax assessment for renewable energy systems	Renewable energy resources rebates/grants Alternative energy bond fund	Industrial recruitment incentive
IN	Renewable energy systems property tax exemption	Alternative power and energy grants Biomass grant program Renewable energy demonstration project grants	
IA	Ethanol based fuels and wind energy equipment sales tax exemption Local option for wind energy special property tax assessment Solar property tax exemption Methane gas conversion property tax exemption	Energy efficiency and renewable energy grants Alternative energy revolving loan fund Building energy management program Iowa renewable fuel fund	
KS	Renewable energy property tax exemption	Renewable energy grants	
KY			
LA			
ME			
MD	Clean energy corporate and personal tax credit Green building corporate and personal tax credit Local option property tax exemption for renewables EV, hybrid, and fuel cell vehicle sales tax exemption Wood heating fuel sales tax exemption	Community energy loan assistance program State energy loan program	
MA	Alternative energy patent exemption Renewable energy equipment sales tax exemption Renewable energy personal income tax exemption Solar and wind corporate excise tax deductions Local property tax	Home energy loans	

State	Tax Incentives	Grants, Loans, Rebates	Other Incentives
	exemptions for hydro		
MI		Community energy project grants	
MN	PV and wind sales tax exemption PV and wind property tax exemption	PV rebates Wind energy agricultural improvement loans Stock loan program	Wind, hydro, digester energy generation incentives Ethanol production incentive
MS		Energy investment loan program	
MO	Wood energy producers corporate tax credit	Low-cost efficiency loan fund	
MT	Alternative energy systems corporate tax credit Wind energy systems corporate tax credit Personal tax credits for wind and residential geothermal systems Renewable energy systems property tax exemption	Alternative energy revolving loan fund	Wind energy systems and manufacturing facility incentives
NE		Low interest loans for energy efficiency	
NV	Renewable energy systems property tax exemption Solar energy producers property tax exemption	Energy efficient appliance loans	
NH	Local option for renewable energy property tax exemption	Renewable energy technology grants	
NJ	Solar and wind energy systems sales tax exemption	NJ clean energy program rebates	
NM			
NY	Solar electric generating equipment personal tax credit Green building corporate tax credit	Renewable R&D grants Energy Smart loans Solar system rebates	
NC	All renewables - corporate and personal tax credits Active solar heating/cooling property tax exemption		Renewable energy equipment manufacture incentives
ND	Geothermal, solar, and wind corporate and personal tax credits and property tax exemptions Large wind property tax incentive and sales tax		

State	Tax Incentives	Grants, Loans, Rebates	Other Incentives
	exemption		
OH	Conversion facilities corporate, sales and property tax exemptions	Renewable energy loans	
OK			
OR	Business energy tax credit Renewable energy system property tax exemption and personal tax credit	Various solar water heater rebates and loan programs Remote water pumping rebates Utility independent home rebates Small scale energy loans	Green building initiative
PA		Alternative fuels incentive grants PV grants	
RI	Renewable energy personal tax credit and property tax exemption Renewable energy sales tax credit	PV and wind rebates Customer education and market building program	Renewable generation supply incentive Small customer incentives for green power marketers
SC		Palmetto Electric rebate program	
SD	Renewable energy systems property tax exemption		
TN		Small business energy loans	
TX	Solar energy device corporate tax deduction Solar systems manufacturer franchise tax exemption Solar and wind systems property tax exemption	Home energy air conditioning and appliance rebates Home energy loans	PV water pump sales program
UT	Renewable energy systems corporate and personal tax credits		
VT	Local option for property tax exemption Sales tax exemption for net metering equipment		
VA	Local option property tax exemption for solar	Green building incentives Low income loans for energy conservation improvements	Solar manufacturing incentive VA Alliance for solar electricity incentives

State	Tax Incentives	Grants, Loans, Rebates	Other Incentives
WA	Sales and use tax exemption High technology product manufacturers excise tax exemption	Off-grid PV buy-down program Rooftop solar loans	
WV	Corporate tax credit and property tax exemption for wind facilities		
WI	Solar and wind energy equipment property tax exemption	Municipal utility solar energy rebates Renewable energy assistance program grants	
WY			PV leasing program

Source: North Carolina Solar Center, Database of State Incentives for Renewable Energy http://www.ies.ncsu.edu/dsire/summarytables/financial.cfm?&CurrentPageID=7, January 17, 2002

3.9 - Federal Incentives – Renewable Energy Production Incentive – Project Summary

REPI Year	Tier	Technology	Cumulative Plant Capacity (kW)	New Plant Capacity (kW)	Total Annual Net Generation (kWh)	States
1994	1	PV	742	742	501,898	CA
1994	1	Wind	5,000	5,000	6,074,618	CA
1994	2	BioPower (open loop)	96,830	96,830	38,678,720	CA , OR , PA
1995	1	PV	1,275	533	933,668	CA
1995	1	Wind	5,080	80	12,975,624	CA , IA
1995	2	BioPower (open loop)	99,290	2,460	138,595,454	CA , OR , PA
1996	1	PV	2,186	911	1,780,449	CA , NY
1996	1	Wind	5,680	600	10,434,434	CA , IA , MI
1996	2	BioPower (open loop)	199,290	100,000	164,735,427	CA , OR , PA
1997	1	PV	2,487	301	1,863,834	CA , FL
1997	1	Wind	5,775	95	7,542,593	CA , IA , MI
1997	2	BioPower (open loop)	253,228	53,938	448,615,348	CA , FL , OR , PA , WA
1998	1	Fuel Cell	200	200	612,215	NY
1998	1	PV	2,663	177	2,100,927	CA , FL , NY
1998	1	Wind	7,238	1,463	4,705,382	AK , CA , IA , MI , WY
1998	2	BioPower (open loop)	307,064	53,836	521,480,500	CA , FL , OR , PA , WA , WI
1999	1	Fuel Cell	200	0	652,706	NY
1999	1	PV	2,978	315	2,783,839	AZ , CA , FL , NY , TX
1999	1	Wind	24,565	17,327	32,726,901	AK , CA , IA , MI , MN , NE , WY
1999	2	BioPower (open loop)	317,719	10,655	469,694,174	CA , FL , OR , PA , WA , WI
2000	1	Fuel Cell	200	0	766,432	NY
2000	1	PV	3,152	173	3,104,928	AZ , CA , FL , NY , TX
2000	1	Wind	29,005	4,440	74,702,688	AK , CA , IA , MI , MN , NE , WY
2000	2	BioPower (open loop)	325,230	7,511	606,367,746	CA , FL , OR , PA , WA , WI

3.10 - Federal Incentives – Renewable Energy Production Incentive – BioPower (open loop) Project Summary

REPI Year	Tier	Technology	Cumulative Plant Capacity (kW)	New Plant Capacity (kW)	Total Annual Net Generation (kWh)	States
1994	2	Landfill Gas	96,830	96,830	38,678,720	CA , OR , PA
1995	2	Landfill Gas	99,290	2,460	138,595,454	CA , OR , PA
1996	2	Animal Waste	100,000	100,000	29,897,768	CA
1996	2	Landfill Gas	99,290	0	134,837,659	CA , OR , PA
1996	2	Total	199,290	100,000	164,735,427	CA , OR , PA
1997	2	Animal Waste	100,000	0	42,220,343	CA
1997	2	Landfill Gas	101,228	1,938	193,534,942	CA , FL , OR , PA
1997	2	Wood Waste	52,000	52,000	212,860,063	WA
1997	2	Total	253,228	53,938	448,615,348	CA , FL , OR , PA , WA
1998	2	Animal Waste	100,000	0	46,637,790	CA
1998	2	Landfill Gas	155,064	53,836	228,559,836	CA , FL , OR , PA , WI
1998	2	Wood Waste	52,000	0	246,282,874	WA
1998	2	Total	307,064	53,836	521,480,500	CA , FL , OR , PA , WA , WI
1999	2	Animal Waste	100,000	0	46,949,282	CA
1999	2	Landfill Gas	162,919	7,855	190,076,865	CA , FL , OR , PA , WA , WI
1999	2	Sewage Gas	2,800	2,800	6,745,066	CA
1999	2	Wood Waste	52,000	0	225,922,961	WA
1999	2	Total	317,719	10,655	469,694,174	CA , FL , OR , PA , WA , WI
2000	2	Animal Waste	100,000	0	45,465,049	CA
2000	2	Landfill Gas	170,430	7,511	335,839,468	CA , FL , OR , PA , WA , WI
2000	2	Sewage Gas	2,800	0	0	CA
2000	2	Wood Waste	52,000	0	225,063,229	WA
2000	2	Total	325,230	7,511	606,367,746	CA , FL , OR , PA , WA , WI

4.0 Forecasts/ Comparisons

4.1 - Projections of Renewable Electricity Net Capacity

(Gigawatts)

Renewable Energy	Data Sources	Projections				
		2000	**2005**	**2010**	**2015**	**2020**
Geothermal	EIA- AEO2002- Reference Case	2.85	3.05	3.57	4.52	5.32
	EIA- AEO2002- High Renewables	2.85	-	4.03	-	7.99
	OPT GPRA- High	2.93	3.94	7.93	10.43	12.93
	OPT GPRA- Low	2.93	4.00	8.40	8.60	8.80
Wind	EIA- AEO2002- Reference Case	2.42	6.82	7.65	8.46	9.06
	EIA- AEO2002- High Renewables	2.42	-	8.72	-	25.27
	OPT GPRA- High	2.76	5.27	18.92	36.96	56.56
	OPT GPRA- Low	2.76	5.2	13.11	21.56	42.66
Solar[1]	EIA- AEO2002- Reference Case	0.36	0.50	0.86	1.00	1.14
	EIA- AEO2002- High Renewables	0.36	-	0.86	-	1.69
	OPT GPRA- High	0.34	0.63	1.87	4.61	8.21
	OPT GPRA- Low	0.34	0.80	2.00	4.50	6.90
Hydroelectric	EIA- AEO2002- Reference Case	80.27	80.76	80.88	80.88	80.88
	EIA- AEO2002- High Renewables	80.27	-	80.88	-	80.88
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A
Biomass/Wood (excluding cogen)	EIA- AEO2002- Reference Case	1.39	1.61	1.73	1.82	1.97
	EIA- AEO2002- High Renewables	1.39	-	1.73	-	2.09
	OPT GPRA- High	1.53	3.89	8.60	10.35	12.10
	OPT GPRA- Low	1.53		4.20	5.20	5.00
Biomass Cogeneration	EIA- AEO2002- Reference Case	5.26	5.92	6.64	7.62	8.43
	EIA- AEO2002- High Renewables	5.26	-	7.27	-	10.21
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A
	OPT GPRA- Low			6.51	7.55	8.39
MSW and LFG	EIA- AEO2002- Reference Case	3.35	4.01	4.39	4.69	4.81
	EIA- AEO2002- High Renewables	3.35	-	4.39	-	4.81
	OPT GPRA- High	2.64	3.84	4.33	4.78	4.99
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A
Total Renewable Energy	EIA- AEO2002- Reference Case	95.89	102.7	105.7	109.0	111.6
	EIA- AEO2002- High Renewables	95.89	-	107.9	-	133.0
	OPT GPRA- High (excludes Hydro, MSW and Biomass Cogeneration)	7.56	13.73	37.32	62.35	89.80
	OPT GPRA- Low (excludes Hydro, MSW and Biomass Cogeneration)	7.56	10.00	27.71	39.86	63.36

Sources: Energy Information Administration (EIA), Projections are from *Annual Energy Outlook 2002, DOE/EIA-0383 (02)* (Washington, D.C., December 2000), Table A8 and F8. [1] Solar thermal and photovoltaic energy.

Table 4.2 Projections of Renewable Electricity Net Generation

(Billion Kilowatthours)

Renewable Energy	Data Sources	Projections 2000	2005	2010	2015	2020
Geothermal	EIA- AEO2002- Reference Case	13.52	15.67	20.20	28.06	34.71
	EIA- AEO2002- High Renewables	13.52	-	24.01	-	56.52
	OPT GPRA- High	23.61	32.10	65.99	86.80	108.74
	OPT GPRA- Low	23.61	22.50	57.00	59.10	60.80
Wind	EIA- AEO2002- Reference Case	5.30	16.74	19.45	21.95	24.07
	EIA- AEO2002- High Renewables	5.30	-	23.44	-	87.06
	OPT GPRA- High	8.84	19.54	78.01	148.77	229.15
	OPT GPRA- Low	8.84	11.70	37.10	66.70	145.20
Solar[1]	EIA- AEO2002- Reference Case	0.92	1.24	2.03	2.40	2.78
	EIA- AEO2002- High Renewables	0.92	-	2.03	-	3.93
	OPT GPRA- High	1.30	1.90	5.63	13.20	26.52
	OPT GPRA- Low	1.30	1.70	4.50	9.70	14.70
Hydroelectric	EIA- AEO2002- Reference Case	276.3	305.6	305.5	304.9	304.3
	EIA- AEO2002- High Renewables	276.3	-	305.5	-	304.3
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A
Biomass/Wood (excluding cogen)	EIA- AEO2002- Reference Case	8.37	14.96	20.86	18.84	15.32
	EIA- AEO2002- High Renewables	8.37	-	21.15	-	16.06
	OPT GPRA- High	10.86	27.57	61.02	73.44	85.86
	OPT GPRA- Low					
Biomass Cogeneration	EIA- AEO2002- Reference Case	29.63	33.72	38.04	44.04	48.99
	EIA- AEO2002- High Renewables	29.63	-	41.85	-	59.92
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A

MSW and LFG	EIA- AEO2002- Reference Case	23.44	28.19	31.07	33.34	34.27
	EIA- AEO2002- High Renewables	23.44	-	31.07	-	34.27
	OPT GPRA- High	18.36	27.64	30.95	34.34	35.84
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A
Total Renewable Energy	EIA- AEO2002- Reference Case	357.5	416.1	437.1	453.5	464.4
	EIA- AEO2002- High Renewables	357.5	-	449.0	-	562.1
	OPT GPRA- High (excludes Hydro, MSW and Biomass Cogeneration)	44.6	81.1	210.7	322.2	450.3
	OPT GPRA- Low (excludes Hydro, MSW and Biomass Cogeneration)	33.8	35.9	98.6	135.5	220.7

Sources: Energy Information Administration (EIA), Projections are from *Annual Energy Outlook 2002, DOE/EIA-0383 (02)* (Washington. D.C., December 2000), Table A8 and F8.

[1] Solar thermal and photovoltaic energy.

4.3 - Projections of Renewable Electricity Carbon Dioxide Emissions Savings

(Million Metric Tons Carbon Equivalent per Year)

** Carbon Emissions Savings based on calculation: (10^9 kWh) * (Btu/kWh) * (TBtu/10^12 Btu) * (MMTCE/TBtu)
Except for Biomass- based on net-bio breakout of carbon emissions (GPRA value + baseline carbon)

	Data Sources	Projections 2000	2005	2010	2015	2020	FY03 GPRA Datacall	
Renewable Energy							Heat Rate	(Btu/kWh)
Geothermal	EIA- AEO2002- Reference Case	2.60	3.11	3.73	4.61	5.32		
	EIA- AEO2002- High Renewables	2.60	-	4.43	-	8.67	Carbon Coefficient	(MMTCE/TBtu)
	OPT GPRA- High	4.55	6.38	12.19	14.26	16.68		
	OPT GPRA- Low	4.55	4.47	10.53	9.71	9.33		
Wind	EIA- AEO2002- Reference Case	1.02	3.32	3.59	3.61	3.69		
	EIA- AEO2002- High Renewables	1.02	-	4.33	-	13.36		
	OPT GPRA- High	1.70	3.88	14.41	24.45	35.15		
	OPT GPRA- Low	1.70	2.32	6.85	10.96	22.27		
Solar[1]	EIA- AEO2002- Reference Case	0.18	0.25	0.37	0.39	0.43		
	EIA- AEO2002- High Renewables	0.18	-	0.37	-	0.60		
	OPT GPRA- High	0.25	0.38	1.04	2.17	4.07		
	OPT GPRA- Low	0.25	0.34	0.83	1.59	2.25		
Hydroelectric	EIA- AEO2002- Reference Case	53.19	60.70	56.42	50.10	46.68		
	EIA- AEO2002- High Renewables	53.19	-	56.42	-	46.68		
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A		
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A		
Biomass/Wood (excluding cogen)	EIA- AEO2002- Reference Case	1.61	2.97	3.85	3.10	2.35		
	EIA- AEO2002- High Renewables	1.61	-	3.91	-	2.46		
	OPT GPRA- High	2.09	6.79	16.09	19.09	22.59	GPRA Biomass- Carbon values	
	OPT GPRA- Low	0.00	0.00	0.00	0.00	0.00		
Biomass Cogeneration	EIA- AEO2002- Reference Case	5.70	6.70	7.03	7.24	7.52		

	EIA- AEO2002- High Renewables	5.70	-	7.73	-	9.19
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A
MSW and LFG	EIA- AEO2002- Reference Case	4.51	5.60	5.74	5.48	5.26
	EIA- AEO2002- High Renewables	4.51	-	5.74	-	5.26
	OPT GPRA- High	N/A	N/A	N/A	N/A	N/A
	OPT GPRA- Low	N/A	N/A	N/A	N/A	N/A
Total Renewable Energy	EIA- AEO2002- Reference Case	68.81	82.65	80.74	74.52	71.25
	EIA- AEO2002- High Renewables	68.81	-	82.94	-	86.22
	OPT GPRA- High (excludes Hydro, MSW and Biomass Cogeneration)	8.59	17.42	43.73	59.97	78.49
	OPT GPRA- Low (excludes Hydro, MSW and Biomass Cogeneration)	6.50	7.13	18.21	22.27	33.86

Sources: Energy Information Administration (EIA), projections are from *Annual Energy Outlook 2002, DOE/EIA-0383 (02)*

(Washington, D.C., December 2000), Table A8 and F8.

[1] Solar thermal and photovoltaic energy.

5.0 Electricity Supply

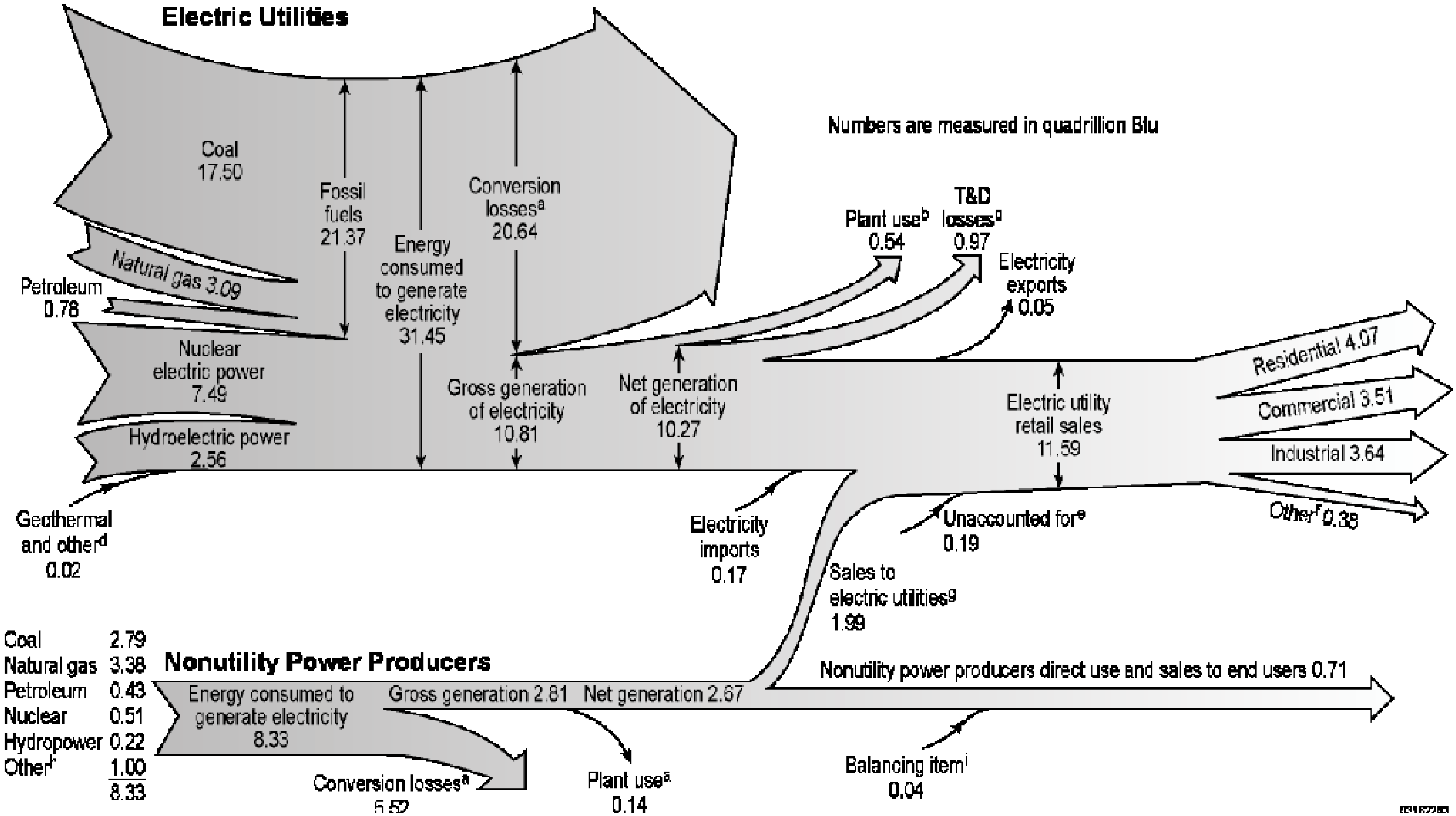
Table 5.1 - U.S. Primary and Delivered Energy – Overview
(Quadrillion Btu per year)

	1980	1990	1999	2000	2010	2020
Primary Consumption by Source						
Petroleum [1]	34.20	33.55	38.25	38.63	45.20	51.99
Natural Gas	20.39	19.29	22.57	23.43	28.85	34.63
Coal	15.42	19.11	21.56	22.34	25.41	27.35
Nuclear	2.74	6.16	7.74	8.03	7.87	7.49
Renewable [2]	5.71	6.19	6.70	6.48	7.90	8.94
Other [3]	0.00	-0.08	0.28	0.38	0.38	0.44
Total Primary	78.46	84.22	97.10	99.29	115.61	130.85
Primary Consumption by Sector						
Residential	15.91	16.41	19.10	19.85	22.24	24.27
Commercial	10.64	12.81	15.84	16.49	19.98	23.18
Industrial	32.19	32.42	35.54	35.50	39.75	43.76
Transportation	19.69	22.54	26.61	27.45	33.66	39.64
Total Primary	78.43	84.18	97.09	99.29	115.63	130.85
Delivered Consumption by Sector						
Residential	7.50	6.46	10.67	11.06	12.40	13.55
Commercial	4.09	3.92	7.70	8.07	9.91	11.64
Industrial	22.64	21.11	27.75	27.62	31.35	34.69
Transportation	19.66	22.49	26.49	27.32	33.50	39.43
Total Delivered	53.89	53.98	72.61	74.07	87.16	99.31

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Tables A1 and A2; EIA*, Annual Energy Review,* DOE/EIA-0384(2000) (Washington, D.C., August 2001), Tables 2.1a-f.

Notes:
[1]Petroleum products supplied, including natural gas plant liquids, crude oil burned as fuel, and ethanol.
[2] End-use consumption, electric utility and nonutility electricity net generation, and net imports of electricity from renewable energy.
[3] Includes net electricity imports, methanol, and liquid hydrogen. Included in Renewable (conventional hydropower) for 1980.\

Table 5.2 - Electricity Flow Diagram



a Approximately two-thirds of all energy used to generate electricity.

b The electric energy used in the operation of power plants, estimated as 5 percent of gross generation.

c Transmission and distribution losses are estimated as 9 percent of gross generation of electricity.

d Wood, waste, wind, and solar energy used to generate electricity.

e Balancing item to adjust for data collection frame differences and nonsampling error.

f Public street and highway lighting, other sales to public authorities, sales to railroads.

g Sales, interchanges, and exchanges of electric energy with utilities.

h Geothermal, wood, waste, wind, and solar energy used to generate electricity.

i Transmission and distribution losses and unaccounted for.

Table 5.3 - Electricity Overview

(Billion Kilowatthours, unless otherwise noted)

	1980	1990	1999	2000	2010	2020
Electric Utility Generation [1]	2,286	2,808	3,392	3,504	4,263	4,983
Nonutility Generation [2]	68	217	321	311	379	452
Net Electricity Generation	2,286	3,025	3,713	3,815	4,642	5,435
Capability (gigawatts)	579	735	783	809	972	1,138
Utility [1]	579	691	730	754	906	1,062
Nonutility [2]	17	45	53	56	66	76
Utility/Nonutility Stocks (end of year)						
Coal (million short tons)	183	156	143	103	NA	NA
Petroleum (million barrels)	135	84	53	41	NA	NA
Imports from Canada/Mexico	25	18	39	48	51	47
Exports to Canada/Mexico	3	16	14	13	16	8
Loss and Unaccounted for [3]	NA	210	234	221	NA	NA
Electric Utility Retail Sales [4]	2,094	2,713	3,324	3,426	4,170	4,916
Nonutility End Use [5]	NA	104	178	277	225	269
Total End Use	NA	2,817	3,502	3,603	4,395	5,185

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Tables A8, A9 and A10 ; EIA, *Annual Energy Review 2000,* DOE/EIA-0384(2000) (Washington, D.C., August 2001), Tables 8.1 and 8.11.

Notes:

[1] As of 1999, grid-connected nonutility generation is included with electric utility generation. Grid-connected nonutility generation contributed 60% of new capacity additions in 2000 and is expected to represent 80% by 2010. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992.

[2] As of 1999, only cogenerators and off-grid nonutility generation.

[3] Energy losses that occur between the point of generation and delivery to the customer.

[4] Includes nonutility sales of electricity to utilities for distribution to end-users. Beginning in 1996, also includes sales to ultimate consumers by power marketers.

[5] Nonutility facility use of onsite net electricity generation, and nonutility sales of electricity to end-users.

Table 5.4 - Consumption of Fossil Fuels by Electric Generators [1]

	1980	1990	1999	2000	2010	2020
Coal (million short tons)	569	806	929	965	1,141	1,254
Distillate Fuel Oil (million barrels) [2]	29	15	35	31	9	10
Residual Fuel Oil (million barrels) [3]	391	209	161	137	75	35
Petroleum Coke (million short tons)	s	2	5	4	NA	NA
Total Petroleum (million barrels) [4]	421	234	201	171	84	45
Natural Gas (billion cubic feet)	3,682	2,787	3,790	4,240	6,850	10,300

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Tables A2, A13 and A16 ;
EIA, *Annual Energy Review 2000,* DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.8.

Notes:
s = < 0.5 million short tons

[1] As of 1999, grid-connected nonutility generation is included with electric utility generation. Grid-connected nonutility generation contributed 60% of new capacity additions in 2000 and is expected to represent 80% by 2010. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992.

[2] Forecast values calculated from quadrillion Btu using conversion factor 5.825 MMBtu/barrel.

[3] Forecast values calculated from quadrillion Btu using conversion factor 6.287 MMBtu/barrel.

[4] Petroleum coke is converted from short tons to barrels by multiplying by 5. Total Petroleum is calculated sum.

Table 5.5 - Fossil Fuel Generation by Age of Generating Units

(Megawatts)

	1980	1990	1999	2000
<5 years	91,041	39,498	34,050	51,783
6-10 years	134,949	53,332	41,373	43,671
11-20 years	145,474	223,877	103,411	91,856
21-30 years	97,476	143,742	225,917	221,659
31-40 years	21,018	91,608	129,053	141,811
41-50 years	4,017	15,053	79,789	85,532
>50 years	4,413	3,038	9,049	12,487
Total	498,388	570,148	622,642	648,799

Source: RDI/FT Energy/Platts Database, query by NREL 1/02.

Note: Total MW does not equal fossil fuel generation capacity cited in Table 6.1.

Table 5.6 - Nuclear Generation by Age of Generating Units
(Megawatts)

	1980	1990	1999	2000
<5 years	16,116	30,219	1,270	1,270
6-10 years	33,423	25,598	4,776	1,215
11-20 years	6,329	48,190	54,177	55,816
21-30 years	309	5,990	43,805	43,858
31-40 years	0	0	2,142	4,012
Total	56,177	109,997	106,170	106,171

Source: RDI/FT Energy/Platts Database, query by NREL 1/02.

Note: Total MW does not equal nuclear generation capacity cited in Table 6.1.

Table 5.7 - Renewable Energy Generating Capacity
(Megawatts)

	1980	1990	1999	2000
Agricultural Residues	105	230	438	438
Biogas	19	360	894	900
Municipal Solid Waste	294	2,203	2,969	2,969
Timber Residues	4,059	6,805	7,986	7,986
Bioenergy Total	4,477	9,598	12,287	12,293
Geothermal	802	2,569	2,719	2,768
Hydro	80,503	90,973	94,183	94,183
Photovoltaic	0.06	4	19	25
Solar Thermal	0	354	354	354
Wind	3.12	1,571	2,635	2,673
Total	85,785	105,069	112,197	112,296

Source: *Renewable Electric Plant Information System (REPiS Database)*, National Renewable Energy Laboratory, 2001, http://www.eren.doe.gov/repis/index.html.

Note: Total does not equal renewable generation capacity cited in Table 6.1

Table 5.8 - Electric Power-Sector Energy Consumption

(Trillion Btu)

	1980	1990	1999	2000	2010	2020
Coal	12,123	16,190	18,950	19,690	22,800	24,670
Natural Gas	3,810	2,882	3,860	4,320	6,980	10,490
Petroleum	2,634	1,250	1,100	930	210	280
Other [1]	0	-80	280	380	380	440
Total Fossil Fuels	18,567	20,242	24,190	25,320	30,370	35,880
Nuclear Electric Power	2,739	6,162	7,736	8,030	7,870	7,490
Hydroelectric Pumped Storage	NA	-36	-65	-58	NA	NA
Conventional Hydroelectric [2]	3,118	3,146	3,210	2,820	3,110	3,100
Wood	3	316	110	110	250	190
Waste	2	137	270	280	380	420
Geothermal [3]	110	344	280	280	500	960
Solar	na	7	9	9	10	20
Wind	na	24	46	51	200	250
Total Renewable Energy	3,232	3,982	3,925	3,550	4,450	4,940
Total Primary Consumption [4]	24,538	30,350	35,786	36,842	42,690	48,310

Sources: EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 2.1f and EIA, *Annual Energy Outlook 2002, DOE/EIA-0383 (2002) (Washington, D.C., December 2001),Tables A2 and A18.*

Notes:

[1] Electricity net imports from fossil fuels; may include some nuclear-generated electricity.

[2] Through 1988, includes all electricity net imports. From 1989, includes electricity net imports derived from hydroelectric power only. In 1980 includes other fossil fuels and pumped storage.

[3] From 1989, includes electricity imports from Mexico that are derived from geothermal energy.

[4] As of 1999, only grid-connected nonutility and electric utility generation. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992.

Table 5.9 - Number of Utilities by Class of Ownership and Nonutilities

	1980	1990	1999	2000
Investor Owned Utilties	240	266	239	240
Federally Owned Utilities	41	10	9	9
Cooperatively Owned Utilities[1]	936	951	900	894
Other Publicly Owned Utilities	1,753	2,010	2,012	2,009
Total Number of Utilities	2,970	3,237	3,160	3,152
Nonutilities			1,930	

Source: EIA, *The Changing Structure of the Electric Power Industry 2000: An Update*; Electrical World: Directory of Electric Power Producers, The McGraw-Hill Companies

Notes:
[1] Co-ops operate in all states except Connecticut, Hawaii, Rhode Island, and the District of Columbia

Table 5.10 – Top 10 Investor-Owned Utilities

Utility by Sales (Million kWh)	**1980**		**1990**		**1999**	
	Rank	Million kWh	Rank	Million kWh	Rank	Million kWh
TXU Electric Co		NA	1	78,340	1	95,927
Florida Power & Light Co		NA	5	65,222	2	84,450
Commonwealth Edison Co		NA	2	70,852	3	83,501
Georgia Power Co		NA	8	53,953	4	70,972
Pacific Gas & Electric Co		NA	3	70,597	5	70,187
Reliant Energy HL&P		NA	6	58,583	6	69,375
Southern California Edison Co		NA	4	70,063	7	67,207
Virginia Electric & Power Co		NA	9	52,122	8	62,650
Duke Energy Corp		NA	7	58,359	9	52,009
Alabama Power Co		NA	12	38,081	10	50,157
PacifiCorp		NA	10	40,288	46	17,846

Utility by Revenue (Million $)						
	Rank	Million $	Rank	Million $	Rank	Million $
Pacific Gas & Electric Co		NA	2	6,513	1	6,786
Southern California Edison Co		NA	1	6,767	2	6,692
Commonwealth Edison Co		NA	3	5,668	3	6,176
TXU Electric Co		NA	6	4,200	4	5,852
Florida Power & Light Co		NA	4	4,803	5	5,830
Consolidated Edison Co-NY Inc		NA	5	4,385	6	4,501
Reliant Energy HL&P		NA	7	3,436	7	4,247
Georgia Power Co		NA	8	3,426	8	4,129
Public Service Electric & Gas Co		NA	10	3,262	9	3,874
Detroit Edison Co		NA	12	3,187	10	3,791
Virginia Electric & Power Co		NA	9	3,299	11	3,782

Source: EIA, *Electric Sales and Revenue*, DOE/EIA -0540 (99) (Washington, D.C., October 2000), Table 17.

Table 5.11 - Top 10 Independent Power Producers Worldwide, 2001

(Megawatts)

Company	Worldwide Capacity (9/01)
AES	60,000
Tractebel	50,000
Calpine	34,900
Entergy Wholesale Operations	30,000
Dynegy	28,000
Edison Mission Energy	28,000
NRG Energy	22,410
Mirant	21,500
Cinergy	21,000
Dominion Generation	21,000

Source: Energy InfoSource, *Merchant Power Producer Quarterly, 3rd Quarter 2001 Edition.*

Table 5.12 - Utility Mergers and Acquisitions

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Planned
Mergers/Acquisitions														
IOU-IOU	4	1	2	1	7	4	1	3	1	5	10	4	10	6
Co-op-Co-op	4	3	2	2	7	2	1	4	2	13	15	15	3	
IOU-Co-op				1	2			1		1				
IOU-Gas [1]									1	5	4	3	6	
Muni-Muni								1				2		
Muni-Co-op										1			1	
Power Authority-IOU											1			
Nonutility-IOU													6	2
Foreign-IOU [2]												2	1	3
Total	8	4	4	4	16	6	2	9	4	25	30	26	27	11
Related Activities														
Name Changes									5	2	7	11	1	
New Holding Company										1	5	4	2	
Moved Headquarters						1								
Ceased Operations											1			

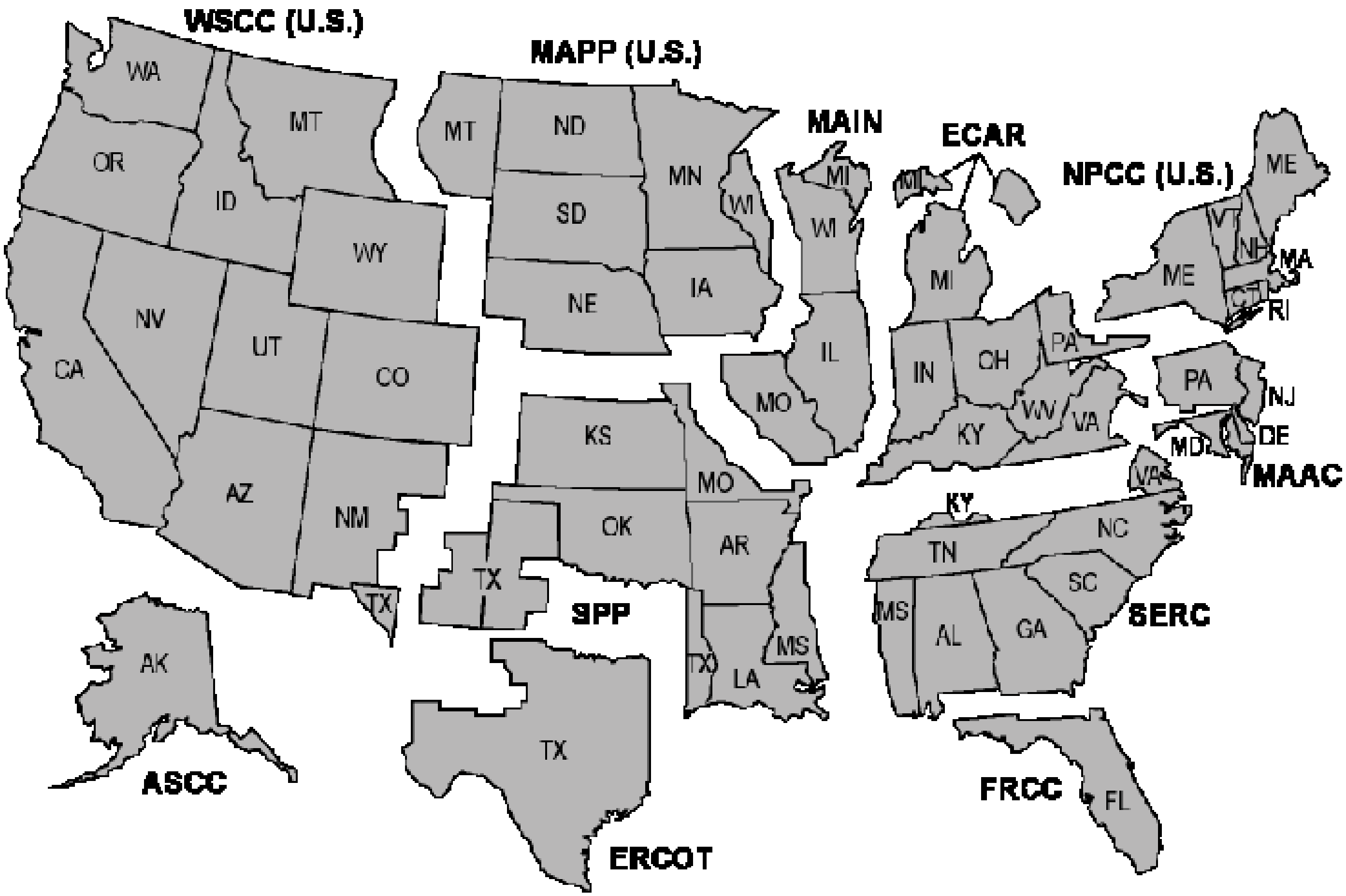
Source: Calculated from Electrical World, D*irectory of Electric Power Producers*, 2001, The McGraw-Hill Companies

Notes:

[1] Gas local distribution company, pipeline, or developer

[2] Excludes Canadian mergers and acquisitions. Includes foreign acquisition of U.S. companies

Table 5.13a - North American Electric Reliability Council Map for the United States



ECAR	East Central Area reliability Coordination
ERCOT	Electric Reliability Council of Texas
FRCC	Florida Reliability Coordinating Council
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interconnected Network
MAPP	Mid-Continent Area Power Pool
NPCC	Northeast Power Coordinating Council
SERC	Southeastern Electric Reliability Council
SPP	Southwest Power Pool
WSCC	Western Systems Coordinating Council
ASCC	Alaska Systems Coordinating Council

Table 5.13b - Census Regions

6.0 Electricity Capability

Table 6.1 - Electric Power Sector Net Summer Capability

(Gigawatts)

	1980	1990	1999	2000	2010	2020
Coal [1]	NA	306.7	313.0	313.5	314.3	337.6
Petroleum/Natural Gas [2]	NA	221.2	257.6	283.4	437.8	581.0
Total Fossil Energy	458.9	527.9	570.6	596.9	752.1	918.6
Nuclear	56	99.6	97.5	97.5	94.3	88.0
Hydroelectric Pumped Storage [3]	NA	19.5	19.2	19.2	19.6	19.6
Conventional Hydroelectric	82.4	74	80.3	80.3	80.9	80.9
Geothermal	0.9	2.7	2.8	2.9	3.6	5.3
Wood [4]	0.1	6.2	6.6	6.7	8.4	10.4
Waste [5]	NA	2.6	3.3	3.4	4.4	4.8
Wind	NA	1.9	2.3	2.4	7.7	9.1
Solar Thermal and Photovoltaic	NA	0.3	0.4	0.5	0.9	1.1
Total Renewable Energy	83.4	87.7	95.7	96.1	105.7	111.6
Total Electric Capability [6]	598.3	734.9	783.0	809.7	971.7	1,137.8

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Tables A9, A17 ; EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.5

Notes:

[1] Coal, fine coal, anthracite culm, bituminous gob, lignite waste, tar coal, waste coal, and coke breeze.

[2] Petroleum, Natural Gas, and Dual Fired steam and combustion turbines consuming fuel oil nos. 1, 2, 4, 5, and 6, crude oil, petroleum coke, kerosene, liquid butane, liquid propane, methanol, liquid byproducts, oil waste, sludge oil, tar oil, blast furnace gas, coke oven gas, butane gas, propane gas, refinery gas, and other process and waste gases derived from coal, petroleum, and natural gas.

[3] Pumped storage included in Conventional Hydro prior to 1989.

[4] Wood, wood waste, black liquor, red liquor, spent sulfite liquor, wood sludge, peat, railroad ties, and utility poles.

[5] Municipal solid waste, landfill gas, methane, digester gas, liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solide byproducts, tires, agricultural byproducts, closed looped biomass, fish oil , and straw.

[6] Includes batteries, chemicals, hydrogen, pitch, sulfur, and purchased steam, which are not separately displayed on this table.

Table 6.2 - Electric Utility Net Summer Capability

(Gigawatts)

	1980	1990	1999	2000	2010	2020
Coal	NA	299.6	304.6	304.6	305.7	329.0
Petroleum/Natural Gas [1]	NA	197.9	219.6	243.3	389.7	524.3
Total Fossil Energy	444.1	497.9	524.2	547.9	695.4	853.3
Nuclear	51.8	99.6	97.5	97.5	94.3	88.0
Hydroelectric Pumped Storage [2]	NA	19.5	19.2	19.2	19.6	19.6
Conventional Hydroelectric	81.7	71.4	79.3	79.3	79.9	79.9
Geothermal	0.9	1.6	2.8	2.9	3.6	5.3
Wood [3]	0.1	0.2	1.4	1.4	1.7	2.0
Waste [4]	NA	0.2	2.8	2.8	3.9	4.3
Wind	NA	s	2.3	2.4	7.7	9.1
Solar Thermal and Photovoltaic	0	s	0.3	0.3	0.5	0.7
Total Renewable Energy	82.7	73.5	88.9	89.1	97.2	101.2
Total Electric Capability [5]	578.6	690.5	729.8	753.7	906.5	1,062.1

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Tables A9, A17 ; EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.6.

Notes:

s = less than 0.05 GW

[1] Petroleum, Natural Gas, and Dual Fired steam and combustion turbine generator facilities, consuming natural gas, fuel oil nos. 1, 2, 4, 5, and 6, crude oil, petroleum coke, and kerosene.

[2] Pumped storage included in Conventional Hydro prior to 1989.

[3] Wood, wood waste, wood sludge, peat, railroad ties, and utility poles.

[4] Municipal solid waste, landfill gas, methane, digester gas, waste alcohol, sludge waste, solid byproducts, tires, and tires.

[5] As of 1999, grid-connected nonutility generation is included with electric utility generation. Grid-connected nonutility generation contributed 60% of new capacity additions in 2000 and is expected to represent 80% by 2010. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992. Includes hot nitrogen and multi-fuel capacity after 1997.

Table 6.3 - Nonutility Power Producer Net Summer Capability

(Gigawatts)

	1980	1990	1999	2000	2010	2020
Coal [1]	N/A	6.6	8.4	8.9	8.6	8.6
Petroleum/Natural Gas [2]	N/A	22.1	38.0	40.1	48.1	56.7
Total Fossil Energy	N/A	30.1	46.4	49.0	56.7	65.3
Nuclear	N/A	s	0	0	0	0
Hydroelectric Pumped Storage	N/A	0	0	0	0	0
Conventional Hydroelectric	N/A	2.5	1.0	1.0	1.0	1.0
Geothermal	N/A	1	s	s	s	s
Wood [3]	N/A	5.6	5.3	5.3	6.6	8.4
Waste [4]	N/A	2.3	0.5	0.5	0.5	0.5
Wind	N/A	1.9	s	s	NA	NA
Solar Thermal and Photovoltaic	N/A	0.3	0.1	0.2	0.4	0.5
Total Renewable Energy	N/A	14.2	6.9	7.0	8.5	10.4
Total Electric Capability [5]	17.3	44.5	53.3	56.0	65.2	75.7

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Tables A9, A17 ; EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.7.

Notes:

[1] Coal, fine coal, anthracite culm, bituminous gob, lignite waste, tar coal, waste coal, and coke breeze.

[2] Petroleum. natural gas, and dual-fired facilities consuming fuel oil nos. 1, 2, 4, 5, and 6, crude oil, petroleum coke, kerosene, liquid butane, liquid propane, methanol, liquid byproducts, oil waste, sludge oil, tar oil, blast furnace gas, coke oven gas, butane gas, propane gas, refinery gas, and other process and waste gases derived from coal, petroleum, and natural gas. Includes 0.9 GW of Other capability (batteries, chemicals, hydrogen, pitch, sulfur, and purchased steam) every year after 1999.

[3] Wood, wood waste, black liquor, red liquor, spent sulfite liquor, wood sludge, peat, railroad ties, and utility poles.

[4] Municipal solid waste, landfill gas, methane, digester gas, liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solide byproducts, tires, agricultural byproducts, closed looped biomass, fish oil, and straw.

[5] As of 1999, only cogenerators and off-grid nonutility generation. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and >1 MW since 1992.

Table 6.4 - Regional Peak Loads

(Megawatts, except as noted)

	1990	1999	2000	1990	1999	2000
	Summer Peak			Winter Peak		
ECAR	79,258	99,239	97,557	67,097	86,239	86,455
ERCOT	42,737	55,529	54,817	35,815	39,164	44,287
FRCC	0	37,493	37,728	0	40,178	40,894
MAAC	42,613	51,645	51,206	36,551	40,220	43,139
MAIN	40,740	51,535	51,271	32,461	39,081	39,742
MAPP (U.S.)	24,994	31,903	32,899	21,113	25,200	27,363
NPCC (U.S.)	44,116	52,855	53,450	40,545	45,227	45,170
SERC	121,149	149,012	151,065	117,231	128,563	134,488
SPP	52,541	38,609	39,383	38,949	27,963	28,375
WSCC (U.S.)	97,389	113,629	116,440	94,252	99,080	102,435
Contiguous U.S.	545,537	681,449	685,816	484,014	570,915	592,348
ASCC (Alaska)	463	NF	NF	613	NF	NF
Hawaii	NF	NF	NF	NF	NF	NF
U.S. Total	546,000	681,449	685,816	484,627	570,915	592,348
Capacity Margin (%)	NA	14.4	14.6	NA	25.6	26.9

Source: EIA, *Annual Energy Review 2000,* DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.14.

NF = data not filed
2000 data are forecast estimates.

Table 6.5 - Electric Generator Cumulative Additions and Retirements

(Gigawatts)

	1980	1990	1999	2000	2010	2020
Cumulative Planned Additions						
Coal Steam					0	0
Other Fossil Steam					0	0
Combined Cycle					6.6	6.6
Combustion Turbine/Diesel					3.7	3.7
Nuclear					0	0
Pumped Storage					0.3	0.3
Fuel Cells					0.2	0.2
Renewable Sources					7.0	8.2
Distributed Generation					0	0
Total Planned Additions					17.7	19.0
Cumulative Unplanned Additions						
Coal Steam					6.2	31.2
Other Fossil Steam					0	0
Combined Cycle					101.9	175.9
Combustion Turbine/Diesel					53.6	105.9
Nuclear					0	0
Pumped Storage					0	0
Fuel Cells					0	0
Renewable Sources					0.6	3.4
Distributed Generation					5.1	19
Total Unplanned Additions					167.4	335.5
Cumulative Retirements						
Coal Steam					5.2	7.0
Other Fossil Steam					18.2	20.5
Combined Cycle					0	0
Combustion Turbine/Diesel					6.1	9.5
Nuclear					3.4	9.7
Pumped Storage					0	0
Fuel Cells					0	0
Renewable Sources					0.1	0.1
Total Retirements					33.1	46.9

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Table A9.
Since December 31, 2000.

Table 6.6 - Combined Heat and Power Capability [1]

(Gigawatts)

	1980	1990	1999	2000	2010	2020
Coal			8.4	8.9	8.6	8.6
Petroleum			2.6	2.6	2.5	2.6
Natural Gas			33.8	35.9	43.5	51.6
Other Gaseous Fuels			0.7	0.7	1.2	1.6
Renewable Sources			5.8	5.8	7.1	8.9
Other Gaseous Fuels			0.9	0.9	0.9	0.9
Total			52.2	54.8	63.8	74.2

Sources: EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Table A9.

Note:

[1] Nameplate capacity reported by cogenerators has been converted to net summer capability by EIA.

Table 6.7 - Transmission and Distribution Circuit Miles

(Miles)

Voltage (kilovolts)	1980	1990	1999	2000	2010
230	NA	70,511	76,762	80,096	85,547
345	NA	47,948	49,250	47,782	51,650
500	NA	23,958	26,038	26,326	27,784
765	NA	2,428	2,453	4,709	4,799
Total	NA	144,845	154,503	158,913	169,780

Sources: NERC, *Electricity Supply and Demand Database*, 2001, ftp://www.nerc.com/pub/sys/all_updl/docs/pubs/2001broc.pdf (bottom of page 3 for data on 2000 and 2010) and EIA, *Electricity Fact Sheets*, www.eia.doe.gov/cneaf/electricty/page/fact_sheets/facts.html (data for 1990 and 1999).

7.0 Electricity Generation

Table 7.1 - Electricity Net Generation

(Billion Kilowatthours)

	1980	1990	1999	2000	2010	2020
Coal [1]	1,162	1,590	1,887	1,968	2,264	2,472
Petroleum [2]	246	124	124	102	38	49
Natural Gas [3]	346	378	561	626	1,153	1,732
Other Gases [4]	0	0	8	6	9	12
Total Fossil Energy	1,754	2,093	2,580	2,702	3,464	4,265
Hydroelectric Pumped Storage[5]	0	-4	-2	1	-1	-1
Nuclear	251	577	728	752	737	702
Conventional Hydroelectric	279	293	316	276	305	304
Geothermal	5	16	15	14	20	35
Wood [6]	0.3	30	37	38	59	64
Waste [7]	0.2	1.3	21	23	31	34
Wind	NA	3	4	5	19	24
Solar Thermal and Photovoltaic	NA	0.6	1	1	2	3
Total Renewable Energy	285	344	395	357	437	464
Other [8]	NA	NA	11	4	4	4
Total Electricity Generation [9]	2,290	3,010	3,712	3,816	4,641	5,434

Sources: EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.2, and EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Tables A8 and A17.

Notes:

[1] Coal, fine coal, anthracite culm, bituminous gob, lignite waste, tar coal, waste coal, and coke breeze.

[2] Fuel oil # 1, 2, 4, 5, and 6, crude oil, petroleum coke, kerosene, liquid butane, liquid propane, methanol, liquid byproducts, oil waste, sludge oil, and tar oil.

[3] Includes electricity from fuel cells in forecast years.

[4] Blast furnace, coke oven, butane, propane, refinery, and other process and waste gases derived from fossil fuels. Included in Natural Gas in 1980 and 1990.

[5] Pumped storage facility production included in conventional hydroelectric power in 1980.

[6] Wood, wood waste, black liquor, red liquor, spent sulfite liquor, wood sludge, peat, railroad ties, and utility poles.

[7] Municipal solid waste, landfill gas, methane, digester gas, liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solide byproducts, tires, agricultural byproducts, closed looped biomass, fish oil , and straw.

[8] Includes chemicals, hydrogen, pitch, sulfur, purchased steam, and batteries not elsewhere displayed.

[9] Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992.

Table 7.2 - Net Generation at Utilities

(Billion Kilowatthours)

	1980	1990	1999	2000	2010	2020
Coal	1,203	1,560	1,837	1,922	2,215	2,423
Petroleum [1]	246	117	110	93	28	38
Natural Gas [2]	346	264	363	417	893	1,414
Total Fossil Energy	1,795	1,941	2,310	2,432	3,136	3,875
Hydroelectric Pumped Storage [3]	0	-4	-2	1	-1	-1
Nuclear	251	577	728	752	737	702
Conventional Hydroelectric	276	283	310	272	301	300
Geothermal	5	9	15	14	20	35
Wood [4]	0.3	0.8	8	8	21	15
Waste [5]	0.2	1.3	18	20	28	31
Wind	s	s	4	5	19	24
Solar Thermal and Photovoltaic	s	s	1	1	1	2
Total Renewable Energy	282	294	356	321	391	407
Total Electricity Generation [6]	2,286	2,808	3,392	3,506	4,263	4,983

Sources: EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.3, and EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Tables A8 and A17.

Notes:
s = <0.5 bkWh
[1] Fuel oil nos. 1, 2, 4, 5, and 6, crude oil, kerosene, and petroleum coke.
[2] Includes supplemental gaseous fuels in 1980 and 1990, electricity from fuel cells in forecast years..
[3] Pumped storage is included in conventional hydroelectric power in 1980.
[4] Wood, wood waste, wood liquors, wood sludge, peat, railroad ties, and utility poles.
[5] Municipal solid waste, landfill gas, methane, digester gas, waste alcohol, sludge waste, solid byproducts, and tires.
[6] As of 1999, grid-connected nonutility generation is included with electric utility generation. Grid-connected nonutility generation contributed 60% of new capacity additions in 2000 and is expected to represent 80% by 2010. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992.

Table 7.3 - Electricity Generation by Nonutilities

(Billion Kilowatthours)

	1980	1990	1999	2000	2010	2020
Coal [1]	NA	31	50	46	49	49
Petroleum [2]	NA	7	14	9	10	11
Natural Gas [3]	NA	114	198	209	260	318
Other Gases [4]	NA	0	8	6	9	12
Total Fossil Energy	NA	152	270	270	328	390
Hydroelectric Pumped Storage	NA	0	0	0		
Nuclear	NA	0.1	0	0		
Conventional Hydroelectric	NA	9	5	4	4	4
Geothermal	NA	7	0.15			
Wood [5]	NA	30	30	30	38	49
Waste [6]	NA	12	3	3	3	3
Wind	NA	3				
Solar Thermal and Photovoltaic	NA	0.6	0.01	0.04	0.81	0.98
Total Renewable Energy	NA	62	39	37	46	58
Other [7]	NA	NA	11	4	4	4
Total Electricity Generation [8]	68	217	320	311	378	452

Sources: EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.4, and EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Tables A8 and A17.

Notes:

[1] Coal, fine coal, anthracite culm, bituminous gob, lignite waste, tar coal, waste coal, and coke breeze.

[2] Fuel oil nos. 1, 2, 4, 5, and 6, crude oil, petroleum coke, kerosene, liquid butane, liquid propane, methanol, liquid byproducts, oil waste, sludge oil, and tar oil.

[3] Natural gas only.

[4] Blast furnace, coke oven, butane, propane, refinery, and other process and waste gases derived from fossil fuels. 1990 included with natural gas.

[5] Wood, wood waste, black liquor, red liquor, spent sulfite liquor, wood sludge, peat, railroad ties, and utility poles.

[6] Municipal solid waste, landfill gas, methane, digester gas, liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solid byproducts, tires, agricultural byproducts, closed loop biomass, fish oil, and straw.

[7] Includes chemicals, hydrogen, pitch, sulfur, purchased steam, and batteries not elsewhere displayed.

[8] As of 1999, only cogenerators and off-grid nonutility generation. Coverage has increased over time from facilities >25 MW before 1989 to include those >5 MW in 1989 and > 1 MW since 1992.

Table 7.4 - Generation and Transmission/Distribution Losses

(Billion kWh)

	1980	1990	1999	2000	2010	2020
Net Generation Delivered	2,290	3,010	3,172	3,816	4,641	5,434
Generation Losses [1]	4,905	5,870	7,727	8,039	8,249	9,179
Transmission and Distribution Losses [2]	NA	210	234	243	279	293

Sources: Calculated from EIA, *Annual Energy Outlook 2002,* DOE/EIA-0383 (2002), (Washington, D.C., December 2001), Tables A2 and A8 and EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Tables 2.1f, 8.1 and 8.2.

Notes:

[1] Generation Losses for all years are calculated by calculating a Gross Generation value in billion kWh by multiplying the energy input in trillion Btu by (1000/3412) and subtracting the Net Generation in billion kWh from the Gross Generation estimate.

[2] Transmission and Distribution Losses (for 1999-2020) = Electricity Needed to be Transmitted - Electricity Sales, where Electricity Needed to be Transmitted = Total Generation from Electric Generators + Cogenerators + Net Imports - Nonutility Generation for Own Use - Generation for Own Use. Energy losses that occur between the point of generation and delivery to the customer, and data collection frame differences and nonsampling error.

Table 7.5 - Electricity Trade

(Billion Kilowatthours)

	1980	1990	1999	2000	2010	2020
Interregional Electricity Trade						
Gross Domestic Firm Power Trade	NA	NA	182	157	103	0
Gross Domestic Economy Trade	NA	NA	117	151	190	205
Gross Domestic Trade	NA	NA	299	308	292	205
International Electricity Trade						
Firm Power Imports from Mexico and Canada	NA	NA	19	24	6	0
Economy Imports from Mexico and Canada	NA	NA	20	24	45	47
Gross Imports from Mexico and Canada	25	18	39	48	51	47
Firm Power Exports to Mexico and Canada	NA	NA	3	7	9	0
Economy Exports to Mexico and Canada	NA	NA	11	6	8	8
Gross Exports to Canada and Mexico	4	16	14	13	16	8

Sources: EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.1 and EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Tables A10.

8.0 Electricity Demand

Table 8.1 - Electricity Sales

(Billion Kilowatthours)

	1980	1990	1999	2000	2010	2020
Residential	717	924	1,145	1,193	1,443	1,672
Commercial	488	751	1,104	1,144	1,475	1,798
Industrial	815	946	1,058	1,071	1,230	1,415
Transportation/Other [1]	74	92	17	18	23	32
Total Sales [2]	2,094	2,713	3,324	3,426	4,171	4,917
Nonutility Direct Use	NA	84	153	147	190	228

Sources: EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002), (Washington, D.C., December 2001), Table A8 and EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.12.

Notes:

[1] Other included public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales until 1998, when included in Commercial. Transportation electricity use reporting starts in 1999.

[2] Includes nonutility sales of electricity to utilities for distribution to end-users. Beginning in 1996, also includes sales to ultimate consumers by power marketers.

Table 8.2 - Demand-Side Management

	1980	1990	1999	2000
Load Management Peakload Reductions (MW)[1]	NA	7,911	13,003	10,048
Energy Efficiency Peakload Reductions (MW)[2]	NA	5,793	13,452	12,873
Total Peakload Reductions (MW)	NA	13,704	26,455	22,921
Energy Savings (Million kWh)	NA	20,458	50,563	53,768
Costs (Million 2000 $)	NA	1,456	1,453	1,631

Sources: EIA, *Annual Energy Review 2000,* DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.13 (through 1999) ,and http://www.eia.doe.gov/cneaf/electricity/page/eia861.html (fourth file in DBF for 2000).

Notes:

[1]Load Management includes programs such as Direct Load Control and Interruptible Load Control, and beginning in 1997, "other types" of demand-side management programs. "Other types" are programs that limit or shift peak loads from on-peak to off-peak time periods, such as space heating and water heating storage systems.

[2]Energy efficiency refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided.

Table 8.3 - Electricity Sales, Revenue, and Consumption by Census Division and State, 2000

Census Division and State	Sales (million kWh)	Revenue (million $)	Average Revenue (¢/kWh)	Electricity Consumption (kWh/person)	Census Division and State	Sales (million kWh)	Revenue (million $)	Average Revenue (¢/kWh)	Electricity Consumption (kWh/person)
New England	**123,013**	**12,072**	**9.8**	**8,836**	**East South Central**	**304,012**	**16,034**	**5.3**	**17,859**
Connecticut	29,917	2,849	9.5	8,785	Alabama	83,692	4,686	5.6	18,819
Maine	17,607	1,739	9.9	13,810	Kentucky	78,429	3,230	4.1	19,405
Massachusetts	51,197	4,864	9.5	8,064	Mississippi	45,166	2,680	5.9	15,877
New Hampshire	9,949	1,154	11.6	8,051	Tennessee	96,725	5,438	5.6	17,001
Rhode Island	8,693	887	10.2	8,292	**West South Central**	**487,032**	**31,039**	**6.4**	**15,488**
Vermont	5,651	578	10.2	9,282	Arkansas	41,435	2,398	5.8	15,499
Middle Atlantic	**341,776**	**30,529**	**8.9**	**8,615**	Louisiana	80,416	5,308	6.6	17,994
New Jersey	70,882	6,437	9.1	8,424	Oklahoma	49,480	2,944	6	14,339
New York	135,754	15,188	11.2	7,154	Texas	315,701	20,389	6.5	15,140
Pennsylvania	135,140	8,904	6.6	11,004	**Mountain**	**222,356**	**13,201**	**5.9**	**12,236**
East North Central	**560,572**	**35,352**	**6.3**	**12,414**	Arizona	61,454	4,412	7.2	11,978
Illinois	136,124	8,957	6.6	10,961	Colorado	43,321	2,598	6	10,072
Indiana	97,116	4,986	5.1	15,972	Idaho	22,862	959	4.2	17,668
Michigan	103,972	7,397	7.1	10,462	Montana	11,718	589	5	12,988
Ohio	158,672	10,333	6.5	13,976	Nevada	28,089	1,719	6.1	14,057
Wisconsin	64,689	3,680	5.7	12,061	New Mexico	18,953	1,247	6.6	10,419
West North Central	**249,363**	**14,727**	**5.9**	**12,962**	Utah	23,151	1,116	4.8	10,367
Iowa	38,812	2,272	5.9	13,263	Wyoming	12,807	561	4.4	25,937
Kansas	35,842	2,245	6.3	13,332	**Pacific Contiguous**	**392,525**	**27,744**	**7.1**	**9,089**
Minnesota	59,851	3,479	5.8	12,166	California	246,652	21,050	8.5	7,282
Missouri	72,882	4,408	6	13,026	Oregon	52,828	2,524	4.8	15,440
Nebraska	23,918	1,261	5.3	13,977	Washington	93,044	4,170	4.5	15,786
North Dakota	9,698	533	5.5	15,101	**Pacific Noncontiguous**	**15,001**	**1,890**	**12.6**	**8,160**
South Dakota	8,360	528	6.3	11,075	Alaska	5,321	531	10	8,487
South Atlantic	**717,116**	**45,724**	**6.4**	**13,852**	Hawaii	9,680	1,360	14	7,990
Delaware	11,137	759	6.8	14,213	**U.S. Total**	**3,412,766**	**228,313**	**6.68**	**12,127**
District of Columbia	10,633	799	7.5	18,587					

Florida	195,278	13,497	6.9	12,218
Georgia	119,922	7,487	6.2	14,649
Maryland	60,936	4,113	6.7	11,505
North Carolina	118,458	7,711	6.5	14,717
South Carolina	76,418	4,193	5.5	19,047
Virginia	96,520	5,746	6	13,636
West Virginia	27,813	1,420	5.1	15,380

Sources: EIA, *Electric Power Annual 2000, Volume 1,* DOE/EIA-0348(2000)/1 (Washington, D.C., August 2001), Table A21 and U.S. Census Bureau PHC-T-2, April 2001, Table 1.

9.0 Prices

Table 9.1 - Price of Fuels Delivered to Electric Generators

(2000 Dollars per Million Btu)

	1980	1990	1999	2000	2010	2020
Distillate Fuel		NA	4.22	6.89	5.23	5.87
Residual Fuel		4.10	2.45	4.11	3.60	3.81
Natural Gas		2.87	2.64	4.41	3.38	3.87
Steam Coal		1.80	1.22	1.20	1.05	0.97
Fossil Fuel Average [1]		2.09	1.51	1.88	1.61	1.85

Sources: EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Table A3, and EIA, *Electric Power Monthly*, Table 26, http://www.eia.doe.gov/cneaf/electricity/epm/epmt26p1.html.

Note:

[1] Since 1999, includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators. Weighted average price.

Table 9.2 - Prices of Electricity Sold
(2000 cents per Kilowatthour)

	1980	1990	1999	2000	2010	2020
Price by End-Use Sector						
Residential	10.2	9.7	8.3	8.3	7.6	7.7
Commercial	10.3	9.1	7.3	7.5	6.8	6.9
Industrial	7.0	5.9	4.4	4.6	4.3	4.5
Transportation/Other [1]	9.0	7.9	7.1	7.4	6.2	6.1
End-Use Sector Average [2]	8.8	8.1	6.7	6.9	6.3	6.5
Price by Service Category						
Generation	NA	NA	4.1	4.3	3.7	3.9
Transmission	NA	NA	0.6	0.6	0.7	0.7
Distribution	NA	NA	2.0	2.0	1.9	1.9

Sources: EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002), (Washington, D.C., December 2001), Table A8 and EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 8.15.

Notes:

[1] Public street and highway lighting, other sales to public authorities, sales to railroads and railways and interdepartmental sales.

[2] Data for 1980 - 2000 are for selected Class A utilities whose electric operating revenues exceeded $100 million during the previous year. Prices represent average revenue per kilowatthour.

Table 9.3 - Revenue from Electric Utility Retail Sales by Sector

(Millions of 2000 Dollars)

	1980	1990	1999	2000	2010	2020
Residential	72,883	89,476	95,035	99,019	109,668	128,744
Commercial	50,127	68,143	80,592	85,800	100,300	124,062
Industrial	56,683	55,470	46,552	49,266	52,890	63,675
Transportation/Other [1]	6,651	7,285	1,207	1,332	1,426	1,952
All Sectors [2]	186,345	220,372	223,386	235,417	264,284	318,433

Sources: Calculated from EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002), (Washington, D.C., December 2001), Table A8 and EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Tables 8.12 and 8.15.

Notes:

[1] Other included public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales until 1998, when included in Commercial. Transportation electricity use reporting starts in 1999.

[2] Since 1999, includes nonutility sales of electricity to utilities for distribution to end-users. Beginning in 1996, also includes sales to ultimate consumers by power marketers.

Table 9.4 - Revenue from Sales to Ultimate Consumers by Sector, Census Division, and State, 2000

(Million Dollars)

Census Division State	Residen-tial	Commer-cial	Industrial	Other[1]	All Sectors[2]	Census Division State	Residen-tial	Commer-cial	Industrial	Other[1]	All Sectors[2]
New England	**4,613**	**4,499**	**2,083**	**216**	**11,410**	**East South Central**	**6,814**	**4,321**	**4,469**	**357**	**15,962**
Connecticut	1,264	1,106	425	57	2,852	Alabama	2,028	1,254	1,357	48	4,687
Maine	467	380	314	19	1,178	Kentucky	1,279	717	1,136	146	3,277
Massachusetts	1,850	2,102	864	99	4,914	Mississippi	1,191	734	657	70	2,652
New Hampshire	481	408	238	16	1,143	Tennessee	2,316	1,617	1,320	93	5,346
Rhode Island	301	301	122	20	743	**West South Central**	**13,920**	**8,468**	**7,386**	**1,409**	**31,183**
Vermont	251	203	120	6	579	Arkansas	1,109	519	726	46	2,399
Middle Atlantic	**12,823**	**13,828**	**4,961**	**1,416**	**33,027**	Louisiana	2,127	1,308	1,599	195	5,229
New Jersey	2,522	3,027	1,013	61	6,624	Oklahoma	1,380	805	570	157	2,912
New York	6,010	7,562	1,389	1,206	16,167	Texas	9,305	5,835	4,491	1,011	20,642
Pennsylvania	4,291	3,238	2,559	149	10,237	**Mountain**	**5,396**	**4,552**	**2,905**	**399**	**13,252**
East North Central	**13,635**	**11,460**	**10,065**	**1,002**	**36,161**	Arizona	2,096	1,572	631	131	4,431
Illinois	3,546	3,207	2,043	549	9,345	Colorado	1,025	998	423	81	2,528
Indiana	1,967	1,214	1,829	58	5,068	Idaho	377	300	262	15	953
Michigan	2,618	2,832	1,898	100	7,449	Montana	254	213	261	2	729
Ohio	4,002	3,102	3,237	240	10,581	Nevada	685	441	560	29	1,715
Wisconsin	1,502	1,104	1,057	54	3,717	New Mexico	413	471	257	96	1,237
West North Central	**6,467**	**4,274**	**3,635**	**406**	**14,781**	Utah	410	412	265	36	1,123
Iowa	1,007	551	665	95	2,319	Wyoming	137	145	246	10	537
Kansas	959	782	465	48	2,254	**Pacific Contiguous**	**11,395**	**11,443**	**6,345**	**562**	**29,745**
Minnesota	1,400	736	1,319	56	3,511	California	8,629	9,502	4,594	380	23,105
Missouri	2,084	1,508	712	67	4,370	Oregon	1,071	774	582	34	2,460
Nebraska	545	382	263	103	1,292	Washington	1,695	1,166	1,170	149	4,180
North Dakota	218	155	121	18	512	**Pacific Noncontiguous**	**666**	**668**	**527**	**34**	**1,895**
South Dakota	254	161	90	19	523	Alaska	212	219	78	26	535
South Atlantic	**22,481**	**14,894**	**6,994**	**1,379**	**45,748**	Hawaii	454	450	448	8	1,360
Delaware	305	239	134	7	685	**U.S. Total**	**98,209**	**78,405**	**49,369**	**7,179**	**233,163**
District of Columbia	130	629	13	26	798						
Florida	7,696	4,511	913	405	13,526						
Georgia	3,386	2,401	1,481	135	7,404						

Maryland	1,905	1,691	417	76	4,089
North Carolina	3,709	2,345	1,569	144	7,767
South Carolina	1,916	1,110	1,246	60	4,332
Virginia	2,823	1,598	804	518	5,742
West Virginia	610	371	417	8	1,405

Source: EIA, *Electric Sales and Revenue 2000* Data Tables, http://www.eia.doe.gov/cneaf/electricity/esr/esr_tabsh.html , Table 1c.

Notes:

[1] Includes sales for public street and highway lighting, to public authorities, railroads and railways, and interdepartmental sales.

[2] Includes Bundled and Unbundled Consumers

Table 9.5 - Production, Operation, and Maintenance Expenses for Major U.S. Investor-Owned and Publicly Owned Utilities

(Million Dollars)

	Investor-Owned Utilities		Publicly Owned Utilities	
	1995	1999	1995	1999
Production Expenses				
Cost of Fuel	29,122	29,826	5,664	6,259
Purchased Power	29,981	43,258	11,988	13,587
Other Production Expenses	9,880	10,470	212	189
Total Production Expenses	68,983	83,555	17,863	20,027
Operation and Maintenance Expenses				
Transmission Expenses	1,425	2,423	788	906
Distribution Expenses	2,561	2,956	1,274	1,521
Customer Accounts Expenses	3,613	4,195	448	557
Customer Service and Information Expenses	1,922	1,889	120	182
Sales Expenses	348	492	29	63
Administrative and General Expenses	13,028	12,951	2,128	1,962
Total Electric Operation and Maintenance Expenses	22,898	24,906	22,651	25,218

Sources: EIA, *Electric Power Annual 1999,* Volume 2, Data Tables, Tables 11 and 13, http://www.eia.doe.gov/cneaf/electricity/epav2/epav2_texttabs.html and EIA, Financial Statistics of Major U.S. Publicly Owned Electric Utilities 1999 Data Tables, Tables 10 and 21, http://www.eia.doe.gov/cneaf/electricity/public/pub_h_tabs.html.

Note: Includes publicly owned generator and nongenerator electric utilities.

Table 9.5a - Operation and Maintenance Expenses for Major U.S. Investor-Owned Electric Utilities

(Million Dollars, unless otherwise indicated)

	1995	1999
Utility Operating Expenses	165,321	182,258
Electric Utility	150,599	167,266
Operation	91,881	108,461
Production	68,983	83,555
Cost of Fuel	29,122	29,826
Purchased Power	29,981	43,258
Other	9,880	10,470
Transmission	1,425	2,423
Distribution	2,561	2,956
Customer Accounts	3,613	4,195
Customer Service	1,922	1,889
Sales	348	492
Administrative and General	13,028	12,951
Maintenance	11,767	12,276
Depreciation	19,885	23,968
Taxes and Other	27,065	22,561
Other Utility	14,722	14,992
Operation (Mills per Kilowatthour) [1]		
Nuclear	9.43	8.93
Fossil Steam	2.38	2.21
Hydroelectric & Pumped Storage	3.69	4.17
Gas Turbine and Small Scale [2]	3.57	5.16
Maintenance (Mills per Kilowatthour) [1]		
Nuclear	5.21	5.13
Fossil Steam	2.65	2.38
Hydroelectric & Pumped Storage	2.19	2.6
Gas Turbine and Small Scale [2]	4.28	4.8

Source: EIA, *Electric Power Annual 1999,* Volume 2, Data Tables, Tables 11 and 13, http://www.eia.doe.gov/cneaf/electricity/epav2/epav2_texttabs.html.

Notes:

[1] Operation and maintenance expenses are averages, weighed by net generation.

[2] Includes gas turbine, internal combustion, photovoltaic, and wind plants.

Table 9.5b - Operation and Maintenance Expenses for Major U.S. Publicly Owned Generator and Nongenerator Electric Utilities

(Million Dollars, except employees)

	1995	1999	2000
Production Expenses			
Steam Power Generation	3,895	4,281	5,420
Nuclear Power Generation	1,277	1,292	1,347
Hydraulic Power Generation	261	281	332
Other Power Generation	231	405	603
Purchased Power	11,988	13,587	16,481
Other Production Expenses	212	189	225
Total Production Expenses	17,863	20,027	24,398
Operation and Maintenance Expenses			
Transmission Expenses	788	906	982
Distribution Expenses	1,274	1,521	1,646
Customer Accounts Expenses	448	557	662
Customer Service and Information Expenses	120	182	233
Sales Expenses	29	63	82
Administrative and General Expenses	2,128	1,962	2,116
Total Electric Operation and Maintenance Expenses	22,651	17,072	30,100
Fuel Expenses in Operation			
Steam Power Generation	2,163	2,871	4,150
Nuclear Power Generation	222	333	316
Other Power Generation	101	189	373
Total Electric Department Employees[1]	73,172	71,265	71,353

Source: EIA, *Financial Statistics of Major U.S. Publicly-Owned Electric Utilities 1999* Data Tables, Tables 10 and 21, http://www.eia.doe.gov/cneaf/electricity/public/pub_h_tabs.html.

Notes:
[1] Number of employees were not submitted by some publicly owned electric utilities because the number of electric utility employees could not be separated from the other municipal employees or the electric utility outsourced much of the work.

Table 9.6 - Environmental Compliance Equipment Costs

	1990	1995	1999	2000	2010	2020
Average Flue Gas Desulfurization Costs at Utilities						
Average Operation & Maintenance Costs (mills/kWh)	1.35	1.16	1.13	N/A	N/A	N/A
Average Installed Costs ($/kW)	118	126	125	N/A	N/A	N/A

Source: EIA, *Electric Power Annual 1999* Volume 2, DOE/EIA-0348(99)/2, (October 2000), Table 29.

10.0 Economic Indicators

Table 10.1 - Consumer Price Estimates for Energy Purchases

(2000 Dollars, per Million Btu)

	1970	1980	1990	1999	2000	2010	2020
Coal	1.36	2.76	1.84	1.24	1.22	1.07	0.98
Natural Gas	2.17	5.37	4.76	4.15	5.43	4.47	4.79
Distillate Fuel	4.27	12.57	9.52	7.36	9.93	9.22	9.33
Jet Fuel	2.69	11.93	7.03	4.81	7.36	5.87	6.37
Liquified Petroleum Gases	5.38	10.58	8.35	9.12	12.06	9.37	9.79
Motor Gasoline	10.49	18.46	11.28	9.67	12.20	11.27	11.28
Residual Fuel	1.55	7.28	3.91	2.55	4.11	3.54	3.75
Other [1]	5.08	13.17	7.17				
Petroleum Total	6.33	13.88	9.24	7.55	10.05	9.19	9.34
Nuclear Fuel	0.66	0.81	0.83	N/A	N/A	N/A	N/A
Wood and Waste	4.75	4.24	2.41	N/A	N/A	N/A	N/A
Primary Energy Total [2]	3.98	8.57	5.57	6.41	8.41	7.61	7.89
Electric Utility Fuel	1.18	3.28	1.81	N/A	N/A	N/A	N/A
Electricity Purchased by End Users	18.34	26.17	23.91	19.72	20.20	18.58	18.97
Total Energy [2]	6.08	12.92	10.25	N/A	N/A	N/A	N/A

Sources: EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002), (Washington, D.C., December 2001), Table A3 and EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 3.3.

Notes:

[1] Asphalt and road oil, aviation gasoline, kerosene, lubricants, petrochemical feedstocks, petroleum coke, special naphtas, waxes, and miscellaneous petroleum products.

[2] The "Primary Energy Total" and "Total Energy" prices include consumption weighted average prices for coal coke imports and coal coke exports that are not shown in the other columns.

Table 10.2 - Economy-Wide Indicators

(Billions of 2000 Dollars, unless otherwise noted)

	1980	1990	1999	2000	2010	2020
GDP Chain Type Price Index (2000 = 1.000)	0.533	0.808	0.979	1.000	1.279	1.707
Real Gross Domestic Product	5,244	7,177	9,477	9,870	13,174	17,682
Real Consumption			6,386	6,696	8,834	11,760
Real Investment			1,776	1,897	2,694	4,230
Real Government Spending	NA	1,484	1,639	1,683	2,024	2,299
Real Exports	358	616	1,107	1,212	2,106	4,314
Real Imports	348	676	1,447	1,639	2,421	4,675
Real Disposable Personal Income			6,762	6,997	9,354	12,517
Consumer Price Index (2000 = 1.000)	0.61	0.93	0.97	1.00	1.32	1.83
Unemployment Rate (percent)			4.23	4.01	4.49	4.04
Housing Starts (millions)			2.00	1.82	1.93	2.01
Gross Output						
Total Industrial	1,683	4,610	5,585	5,898	7,671	9,841
Non-Manufacturing	581	1,055	1,153	1,211	1,411	1,682
Manufacturing	1,102	3,555	4,432	4,686	6,260	8,159
Energy-Intensive Manufacturing			1,231	1,282	1,458	1,643
Non-Energy-Intensive Manufacturing			3,200	3,404	4,802	6,516
Population (all ages, millions)	226.5	248.7	272.7	281.4	299.9	324.9
Employment Non-Agriculture (millions)			127.5	130.1	145.2	154.5
Employment Manufacturing (millions)	20.4	19.2	17.6	17.5	16.3	15.3

Sources: EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Table A20, EIA, Annual Energy Review 2000, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table E.1, U.S. Census Bureau, National Population Projections Summary Files, http://www.census.gov/population/www/projections/natsum-T3.html, Decennial Census Population and Housing Counts, CPH-2-1, Table 16, http://www.census.gov/population/censusdata/table-16.pdf, Bureau Of Economic Analysis, National Income and Products Accounts Tables (NIPA), Tables 1.2, 3.8, 6.4 (B-C) and 7.1, http://www.bea.doc.gov/bea/dn/nipaweb/NIPATableIndex.htm#P, and BEA 1977-2000 Gross Output by Detailed Industry (NDN-0288)

Table 10.3 - Composite Statements of Income for Major U.S. Publicly Owned Generator and Investor-Owned Electric Utilities, 1999

(Million Dollars)

	Publicly Owned Generator Electric Utilities	Investor-Owned Electric Utilities [1]
Operating Revenue - Electric	26,767	197,578
Operating Expenses - Electric	21,274	167,266
Operation	15,386	108,461
Maintenance	1,686	12,276
Depreciation and Amortization	3,505	23,968
Taxes and Tax Equivalents	697	23,800
Operating Income	5,493	31,902
Other Income and Deductions	938	1,665
Total Income Before Interest Charges	6,431	33,567
Net Interest Charges	4,468	13,691
Net Income before Extraordinary Charges	1,963	19,876
Less Extraordinary Items	186	2,793
Net Income	1,777	17,083

Source: EIA *Electric Power Annual 1999* (Volume 2) Data Tables, Tables 8 and 14, http://www.eia.doe.gov/cneaf/electricity/epav2/epav2_texttabs.html

Note:
[1] Preliminary data

11.0 Environ-ment Indicators

Table 11.1 - Emissions from Electricity Generators

(Thousand short tons of gas)

	1990	1999	2000	2010	2020
Coal Fired					
Carbon Dioxide	1,727,301	2,021,154	2,039,106	2,359,560	2,558,783
Sulfur Dioxide	15,711	12,158	NA	NA	NA
Nitrogen Oxide	6,881	6,934	NA	NA	NA
Petroleum Fired					
Carbon Dioxide	119,411	125,207	80,417	17,376	19,633
Sulfur Dioxide	842	942	NA	NA	NA
Nitrogen Oxide	204	167	NA	NA	NA
Gas Fired					
Carbon Dioxide	316,583	340,999	246,907	406,528	610,600
Sulfur Dioxide	2	2	NA	NA	NA
Nitrogen Oxide	918	676	NA	NA	NA
Other [1]					
Carbon Dioxide	155,641	15,367	NA	NA	NA
Sulfur Dioxide	235	104	NA	NA	NA
Nitrogen Oxide	122	95	NA	NA	NA
Total					
Carbon Dioxide	2,318,936	2,502,728	2,366,430	2,783,464	3,189,016
Sulfur Dioxide	16,790	12,450	11,050	9,700	8,950
Nitrogen Oxide	8,125	5,710	4,280	4,040	4,180
Methane	25	29	NA	NA	NA
Nitrous Oxide	27	31	NA	NA	NA
Sulfur Hexafluoride [2]	1.5	0.7	NA	NA	NA

Sources: EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, D.C., December 2001), Tables A8 and A19, EIA, Annual Energy Review 2000, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 12.6, EPA, 2001 National Emissions Tables, Tables 2-15, 2-16, http://www.epa.gov/globalwarming/publications/emissions/us2001/tables.html, EPA, U.S. High GWP Emissions 1990-2010: Inventories Projections and Opportunities for Reductions EPA-ooo-F-97-000, (June 2001), Tables 3.2 and 3.3 , http://www.epa.gov/globalwarming/publications/emissions/highgwp_emit.pdf.

Notes:

[1] Plants fired by light oil, methane, coal-oil mixture, propane gas, blast furnace gas, wood and refuse

[2] Sulfur hexafluoride (SF6) is a colorless, odorless, non-toxic, and non-flammable gas used as an insulator in electric T&D equipment. SF6 has a 100-year global warming potential that is 23,900 times that of carbon dioxide and has an atmospheric lifetime of 3,200 years.

Table 11.2 - Installed Nameplate Capacity of Utility Steam-Electric Generators With Environmental Equipment

(Megawatts)

	1990	1999
Coal Fired		
Particulate Collectors	315,681	324,109
Cooling Towers	134,199	146,377
Scrubbers	69,057	89,666
Total[1]	317,522	331,379
Petroleum and Gas Fired		
Particulate Collectors	33,639	29,371
Cooling Towers	28,359	29,142
Scrubbers	65	0
Total[1]	59,372	55,812
Total		
Particulate Collectors	349,319	353,480
Cooling Towers	162,557	175,520
Scrubbers	69,122	89,666
Total[1]	376,894	387,192

Source: EIA, *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, D.C., August 2001), Table 12.7.

Notes:

[1]Components are not additive because some generators are included in more than one category.

1999 data are preliminary.

Data cover only plants with fossil-fuel steam-electric capacity >100 MW.

Table 11.3 - EPA-Forecasted Nitrogen Oxide, Sulfur Dioxide and Mercury Emissions from Electric Generators

	2000	2005	2010
NOx (Thousand Tons)			
Base Case [1]	6,066	6,487	6,272
Worse Case [2]	6,407	6,891	7,176
Better Case [3]	5,993	6,108	6,052
SO_2 (Thousand Tons)			
Base Case [1]	10,716	10,880	9,408
Worse Case [2]	10,257	10,647	9,763
Better Case [3]	11,037	10,807	9,323
Mercury (Tons)			
Base Case [1]	60.0	64.5	60.7
Worse Case [2]	63.3	66.9	68.1
Better Case [3]	58.9	60.3	59.3

Source: Environmental Protection Agency (EPA), EPA's Forecast of Electric Power Generation and Air Emissions, Tables 4, 8, and 11, http://www.epa.gov/capi/capi/frcsttbl.html#goto8.

Notes:

[1] Base Case is the NERC forecast adjusted for the Climate Change Action Plan, with 15-20% reserve margins, 75% transmission transfer capacity, 65 year limit of >50 MW coal plants, minor reduction in nuclear capacity to 90 GW, fossil plant availability increases to 85%, combined cycle heat rates reduce to 5,687 Btu/kWh, nonhydro renewables based on AEO96.

[2] Worse Case is similar to the Base Case with the following key difference: 25% reduced demand, 13-18% reserve margins, 80% transmission transfer capacity, 80 year limit on >50 MW coal plants, greaer reduction in nuclear capacity to 84 GW, fossil plant availability increases to 90%, combined cycle heat rates reduce to 6752 Btu/kWh.

[3] Better Case is similar to Base Case, but adjusts for Climate Change with a greater reduction in demand, 70% reserve margins, 60 year limit on >50 MW coal plants, and non-hydro renewables with 40% cost reduction by 2005.

Table 11.4 - Market Price Indices for Emissions Trading in the South Coast Air-Quality Management District

	1996	1997	1998	1999	2000	2001	2005	2010
Market Price Indices [1]								
RECLAIM Trading Credit ($/lb) [2]								
Nitrogen Oxide	0.05	0.08	0.20	0.90	42.69	11.11	6.95	6.58
Sulfur Dioxide	0.15	0.08	0.34	0.29	1.14	6.82	4.73	4.73
Emission Reduction Credit ($/lb/day) [3]								
Nitrogen Oxide	2,070	2,908	4,515	4,560	7,675	16,809	NA	NA
Sulfur Dioxide	1,367	1,740	1,687	1,687	3,721	7,184	NA	NA
Particulate Matter (<10 microns)	2,418	1,947	1,981	3,175	6,942	19,030	NA	NA
Reactive Organic Gas	1,075	754	744	735	1,904	1,869	NA	NA
Carbon Dioxide	NA	NA	NA	NA	1,000	7,259	NA	NA

Source: Cantor Fitzgerald EBS, SCAQMD RTC/ERC MPI History, http://www.emissionstrading.com.

Notes:

[1] Market Price Indices (MPIs) reflect current market conditions for a particular date. Dates used here are end of year: 11/12/96, 12/29/97, 12/21/98, 12/27/99, 12/28/00, and 12/7/01. Prices are an average of the most recent price, lowest bid, and highest bid for RTC and ERC transactions executed by Cantor Fitzgerald and/or reported by the South Coast Air Quality Management District (SCAQMD) for 2,000 pounds or more of RTCs or 10 lbs/day or more of ERCs. SCAQMD was chosen because it is the region with the greatest number of emissions traded.

[2] In the RECLAIM program, the RECLAIM Trading Credit (RTC) is a limited authorization to emit a RECLAIM pollutant in accordance with the restrictions and requirements of the RECLAIM rules. Each RTC has a denomination of one pound of RECLAIM pollutant and a term of one year, and can be held as part of a facility's Allocation or alternatively may be evidenced by an RTC Certificate.

[3] Emissions Reduction Credits (ERCs) are reductions in emissions that have been recognized by the relevant local or state government air agency as being real, permanent, surplus, and enforceable. ERCs are usually measured as a weight over time (e.g., pounds per day or tons per year). Such rate-based ERCs can be used to satisfy emission offset requirements of new major sources and new major modifications of existing major sources.

Table 11.5 - Origin of 2000 Allowable SO_2 Emissions Levels

Type of Allowance Allocation	Number of Allowances	Explanation of Allowance Allocation Type
Initial Allocation [1]	9,166,614	Initial Allocation is the number of allowances granted to units based on the product of their historic utilization and emissions rates (performance standards) specified in the Clean Air Act and other provisions of the Act.
Early Reduction Credits	416,989	Early Reduction Credit allowances were given to eligible Phase II units for voluntary emissions reductions made between January 1, 1995 and January 1, 2000.
Allowances for Substitution Units	10,636	A lawsuit settlement allowed for a small amount of allowances to be allocated for Substitution Units in 2000 instead of an earlier year during Phase I.
Allowance Auctions	250,000	Allowance Auctions provide allowances to the market that were set aside in a Special Allowance Reserve when the initial allowance allocation was made.
Opt-in Allowances	97,824	Opt-in Allowances are provided to units entering the program voluntarily. There were 11 opt-in units in 2000.
Small Diesel Allowances	24,468	Small Diesel Allowances were allocated annually to small diesel refineries that produced and desulfurized diesel fuel during the previous year. These allowances were earned in 1999, which was the last year of the small diesel program
Total 2000 Allocation	9,966,531	
Banked Allowances	11,607,955	Banked Allowances are those held over from 1995 through 1999, which can be used for compliance in 2000 or any future year.
Conservation and Renewable Energy Allowances	9,054	These allowances come from a special reserve set aside when the initial allowance allocation was made. They are awarded to utilities that undertake efficiency and renewable energy measures. These are year 1999 allowances that were allocated in year 2000.
Total 2000 Allowable	21,583,540	

Source: EPA, *Acid Rain Program: Annual Progress Report 2000*, Document EPA-430-R-01-008, Exhibit 5.

Note:

[1] The total year 2000 initial allocation was 9,191,897. A total of 25,283 allowances were surrendered by units that exceeded their 1999 Phase I Extension projected emissions limit, and were subject to Phase I substitution unit provisions.

12.0 Conversion Factors

Table 12.1 - Renewable Energy Impacts Calculation

Conversion Formula:	*Step 1*	*Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
	Step 2	*Annual Electricity Generation (D) / Competing Heat Rate (E) = Annual Output (F)*
	Step 3	*Annual Output (F) x Emissions Coefficient (G) = Annual Emissions Displaced (H)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**
(A) Capacity (kW)	2,420,000	2,850,000	1,390,000	79,000,000	10,000
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	51.6%	22.5%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	7,631,712,000	22,469,400,000	9,741,120,000	357,092,640,000	19,710,000
(E) Competing Heat Rate (Btu/kWh)	10,000	10,000	10,000	10,000	10,001
(F) Annual Output (Trillion Btu)	76	225	97	3,571	0
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	1.361	4.006	1.737	63.670	0.004

Sources: Capacity: EIA, Annual Energy Outlook 2002, Table A17, 2001.
Capacity Factors: Estimates based on DOE, Renewable Energy Technology Characterizations, 1997 and Program data
Carbon Emission Coefficient: DOE, GPRA2003 Data Call, Appendix B, page B-16, 2002.

Table 12.2 - Number of Home Electricity Needs Met Calculation

Conversion Formula:	*Step 1*	*Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
	Step 2	*Annual Electricity Generation (D) / Average Consumption (E) = Number of Households (F)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**
(A) Capacity (kW)	2,420,000	2,850,000	1,390,000	79,000,000	10,000
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	59.0%	22.5%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	7,631,712,000	22,469,400,000	9,741,120,000	408,303,600,000	19,710,000
(E) Average Annual Household Electricity Consumption (kWh)	10,582	10,583	10,584	10,585	10,586
(F) Number of Households	721,198	2,123,160	920,363	38,573,793	1,862

Sources: Capacity: EIA, Annual Energy Outlook 2002, Table A17, 2001
Capacity Factors: Estimates based on DOE, Renewable Energy Technology Characterizations, 1997 and Program data

Table 12.3 - Coal Displacement Calculation

Conversion Formula: *Step 1* *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) x Conversion Efficiency (E) = Total Output (F)*
Step 3 *Total Output (F) / Fuel Heat Rate (G) = Quantity Fuel (H)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**
(A) Capacity (kW)	2,420,000	2,850,000	1,390,000	79,000,000	10,000
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	60.0%	22.5%
(C) Annual Hours	8760	8760	8760	8760	8760
(D) Annual Electricity Generation (kWh)	7,631,712,000	22,469,400,000	9,741,120,000	415,224,000,000	19,710,000
(E) Conversion Efficiency (Btu/kWh)	10,000	10,000	10,000	10,000	10,000
(F) Total Output (Btu)	76,317,120,000,000	224,694,000,000,000	97,411,200,000,000	4,152,240,000,000,000	197,100,000,000
(G) Coal Heat Rate (Btu per short ton)	20,525,000	20,525,000	20,525,000	20,525,000	20,525,000
(H) Coal (short tons)	3,718,252	10,947,333	4,745,978	202,301,583	9,603

Sources: Capacity: EIA, Annual Energy Outlook 2002, Table A17, 2001.
Capacity Factors: Estimates based on DOE, Renewable Energy Technology Characterizations, 1997 and Program data

Table 12.31 - National SO_2 and Heat Input Data

	1980	1985	1990	1999	2000	2010	2020
SO_2 (lbs)	34,596,164,000	32,184,330,000	31,466,762,000	24,904,614,200	22,404,284,000		
Heat (Btu)	17,859,931	18,414,434	19,684,248	24,928,629	25,598,096		
SO_2 Heat Factor (lb/Btu)	1937.1	1747.8	1598.6	999.0	875.2		

Source: EPA, *Acid Rain Program Compliance Report 2000, Emission Scorecard*, Table A1

Table 12.32 - SO_2, NOx, CO_2 Emission Factors for Coal Fired and Non-Coal Fired Title IV Affected Units

	1996	1999	2000	2010	2020
SO_2 (lbs/Btu)					
Coal	1,241	1,166	1,036		
Non-Coal	247	267	200		
Total	1,096	999	875		
NO_x (lbs/Btu)					
Coal	568	485	444		
Non-Coal	233	244	210		
Total	518	440	399		
CO_2 (lbs/Btu)					
Coal	206,139	205,586	205,646		
Non-Coal	132,978	132,001	133,094		
Total	195,521	191,956	191,678		

Source: EPA, Acid Rain Program Compliance Report 2000, Emission Scorecard, Table 1

Table 12.33 - Sulfur Dioxide, Nitrogen Oxide, and Carbon Dioxide Emission Factors, 1999

Fuel	Boiler Type/ Firing Configuration	Emission Factors Sulfur Dioxide [1]	Nitrogen Oxides [2]	Carbon Dioxide [3]	Fuel	Boiler Type/ Firing Configuration	Emission Factors Sulfur Dioxide [1]	Nitrogen Oxides [2]	Carbon Dioxide [3]
Utility					**Nonutility**				
Coal and Other Solid Fuels		lbs per ton	lbs per ton	lbs per 10^6 Btu	Coal and Other Solid Fuels		lbs per ton	lbs per ton	lbs per 10^6 Btu
Petroleum Coke[5]	fluidized bed[4]	39.0 x S	21	225.13	Liquid Waste	all types	2.8	2.3	163.29
	all others	39.0 x S	21	225.13	Municipal Solid Waste	all types	1.7	5.9	189.48
Refuse	all types	3.9	5	199.82	Petroleum Coke[7]	all types	39.0 x S	14	225.13
Wood	all types	0.08	1.5	0	Sludge, Sludge Wood/Waste	all types	2.8	5	0
					Sulfur	all types	7	0	0
					Waste Byproducts	all types	1.7	2.3	163.29
					Wood/Wood Waste	all types	0.08	1.5	0
Petroleum and Other Liquid Fuels		lbs per 10^3 gal	lbs per 10^3 gal	lbs per 10^6 Btu	Petroleum and Other Liquid Fuels		lbs per 10^3 gal	lbs per 10^3 gal	lbs per 10^6 Btu
Resudual Oil[6]	tangential	157.0 x S	32	173.72	Heavy Oil[6]	all types	157.0 x S	47	173.72
	vertical	157.0 x S	47	173.72	Light Oil[6], Kerosene	all types	142.0 x S	20	159.41
	all others	157.0 x S	47	173.72	Diesel	all types	142.0 x S	20	161.27
Distillate Oil[6]	all types	157.0 x S	24	161.27	Butane (liquid)	all types	0.09	21	143.2
Propane (liquid)	all types	86.5	19	139.04	Oil Waste	all types	147.0 x S	19	163.61
					Propane (liquid)	all types	0.5	19	139.04
					Sludge Oil	all types	147.0 x S	19	0
Natural Gas and Other Gaseous Fuels		lbs per 10^6 cf	lbs per 10^6 cf	lbs per 10^6 Btu	Natural Gas and Other Gaseous Fuels		lbs per 10^6 cf	lbs per 10^6 cf	lbs per 10^6 Btu
Natural Gas	tangential	0.6	170	116.38	Natural Gas	all types	0.6	280	116.97
	all others	0.6	280	116.38	Butane (gas)	all types	0.6	21	143.2
Blast Furnance Gas	all types	950	280	116.38	Propane (gas)	all types	0.6	19	139.04

Source: Energy Information Administration (EIA), Electric Power Annual 1999 Volume II, DOE/EIA-0348(99)/2, (October 2000), (Table A3).

http://www.eia.doe.gov/cneaf/electricity/epav2/html_tables/epav2ta3p2.html

Notes:

[1]Uncontrolled sulfur dioxide emission factors. "x S" indicates that the constant must be multiplied by the percentage (by weight) of sulfur in the fuel. Sulfur dioxide emission estimates from facilities with flue gas desulfurization equipment are calculated by multiplying uncontrolled emission estimates by one minus the reported sulfur removal efficiencies. Sulfur dioxide emission factors also account for small quantities of sulfur trioxide and gaseous sulfates.

[2]Parenthetic values are for wet bottom boilers; otherwise dry bottom boilers. If bottom type is unknown, dry bottom is assumed. Emission factors are for boilers with a gross heat rate of 100 million Btu per hour or greater.

[3]Uncontrolled carbon dioxide emission estimates are reduced by 1% to account for unburned carbon.

[4]Sulfur dioxide emission estimates from fluidized bed boilers assume a sulfur removal efficiency of 90%.

[5]Emission factors for petroleum coke are assumed to be the same as those for anthracite. If the sulfur content of petroleum coke is unknown, a 6 percent sulfur content is assumed.

[6]Oil types are categorized by Btu content as follows: heavy (greater than or equal to 144,190 Btu per gallon), and light (less than 144,190 Btu per gallon). cf = Cubic Feet. gal = U.S. Gallons. lbs = Pounds.

Table 12.4 - Global Warming Potentials (GWP)
(100-year time horizon)

Gas	GWP
Carbon dioxide (CO2)	1
Methane (CH4)*	21
Nitrous oxide (N2O)	310
HFC-23	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF4	6,500
C2F6	9,200
C4F10	7,000
C6F14	7,400
SF6	23,900

Source: EPA, Executive Summary of the 2001 Inventory of U.S. Greenhouse Gas Emissions and Sinks, Global Warming Potentials, EPA 236-R-01-001 (April 2001), http://www.epa.gov/globalwarming/emissions/national/gwp.html, TABLE or PAGE???

[1]The methane GWP includes direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO2 is not included.

The GWP of a greenhouse gas is the ratio of global warming, or radiative forcing – both direct and indirect – from one unit mass of a greenhouse gas to that of one unit mass of carbon dioxide over a period of time.

Table 12.5 - Approximate Heat Content of Selected Fuels for Electric Power Generation

Fossil Fuels [1]	
Residual Oil (million Btu per barrel)	6.287
Distallate Oil (million Btu per barrel)	5.825
Natural Gas (Btu per million cubic ft)	1,019
Coal (million Btu per Short Ton)	20.479
Biomass Materials [2]	
Switchgrass Btu per pound	7,341
Bagasse, Btu per pound	6,065
Rice Hulls, Btu per pound	6,575
Poultry Litter, Btu per pound	6,187
Solid wood waste, Btu per pound	6-8,000

Sources

1. EIA, Annual Energy Outlook, DOE/EIA-0384(00) (Washington, D.C., August 2001), Appendix ii
2. Animal Waste Screening Study, Electrotek Concepts, Inc., Arlington, Va. June 2001.

Table 12.6 - Approximate Heat Rates for Electricity

(Btu per Kilowatthour)

	1980	1990	1999	2000	2010	2020
Fossil-Fueled Steam-Electric Plants[1]	10388	10402	10346	10346		
Nuclear Steam-Electric Plants	10908	10680	10623	10623		
Geothermal Energy Plants[2]	21639	21096	21017	21017		

Source: EIA, *Annual Energy Review*, DOE/EIA-0384(00) (Washington, D.C., August 2001), Table A6

Notes:

[1] Used as the thermal conversion factor for hydroelectric power generation, and for wood and waste, wind and solar energy consumed for the generation of electricity.

[2] Used as the thermal conversion factor for geothermal energy consumed for the generation of electricity

Table 12.7 - Heating Degree Days by Month

	1980	1990	1999	2000	2010	2020	Normal[1]
January	887	728	861	879			948
February	831	655	647	636			768
March	680	535	645	493			611
April	338	321	319	345			339
May	142	184	139	121			150
June	49	29	31	34			36
July	5	6	5	5			7
August	10	10	12	6			13
September	54	56	62	85			69
October	316	246	275	246			271
November	564	457	413	611			528
December	831	789	760	999			836
Total	4707	4016	4169	4460			4576

Source: EIA, *Annual Energy Review 2000,* DOE/EIA-0384 (00) (Washington, D.C., August 2001), Table 1.7

Notes:

[1] Based on calculations of data from 1961-1990

Table 12.8 - Cooling Degree Days by Month

	1980	1990	1999	2000	2010	2020	Normal[1]
January	9	15	12	6			7
February	4	14	11	8			7
March	13	21	12	20			16
April	23	29	40	31			31
May	95	86	94	131			95
June	199	234	219	221			208
July	374	316	374	293			317
August	347	291	305	299			287
September	192	172	152	167			154
October	42	57	55	54			52
November	10	16	17	11			13
December	5	9	6	4			7
Total	1313	1260	1297	1245			1193

Source: EIA, *Annual Energy Review 2000,* DOE/EIA-0384 (00) (Washington, D.C., August 2001), Table 1.7

Notes:

[1] Based on calculations of data from 1961-1990

13.0 Q&As

Selected Congressional Q&As from FY01 and FY02
Crosscutting

Question: What are your views on the technology advancements that have been made in renewable energy? Do you believe that renewable energy can and should play and important role in our nation's energy mix?

Answer: Twenty years ago renewable energy was generally produced at a very high cost and in an inefficient manner. Since then, renewable energy technologies such as wind, solar, biomass, and geothermal -- have made remarkable progress. For example, in the early 1980s the cost of electricity from wind turbines ranged from $0.30 - $0.40 per kiloWatt-hour (kWh), to more than $1.00 per kWh from photovoltaic systems, and to at least $0.16 cents per kWh from geothermal plants. Biomass ethanol for transportation cost more than $1.00 per gallon. Advancements achieved through research and development conducted by the Department of Energy and its partners have made significant improvements B in production costs, system reliability and in reduced energy production costs. Today, the cost of power from wind energy in good wind regions can be as low as $0.04 - $0.06 per kWh, electricity from photovoltaics now range from $0.12 to $0.20 per kWh, geothermal plants can provide electric power for $0.05 - $0.08 per kWh, and research on biomass ethanol is on track for achieving its 2010 production cost goal of $0.72 per gallon.

While these achievements are truly impressive, substantial work remains to be done. I know that the role of each technology has to be put in perspective with regard to the current energy prices and situations. Clearly, competition and a number of technology advances in the electric power sector has led to dramatic decreases in the price of power from new sources of generation. For example, natural gas-fired combustion turbine technology is capable of providing power at about $0.03 per kWh today. Still, I believe that the incredible growth and demand for additional power across the Nation suggest that we need to develop a wide-ranging portfolio of domestic-based options to meet the different needs and match the resources of the various regions of our country. For the near term, clean renewable technologies can already provide cost-competitive power in certain applications and can provide competitive peak power and help reduce energy price volatility. In the longer term, renewable energy technologies can meet a substantial portion of our nation's clean energy needs. Therefore, I believe that renewable energy technologies -- including advanced hydropower and renewable/fossil hybrid systems -- can and should play an important role in the U.S. energy future.

Question: The Bush-Cheney campaign literature stated: “George W. Bush understands the promise of renewable energy and believes strongly in encouraging alternative sources such as wind, biomass, and solar.” Do these budget cuts for renewable programs represent a reversal of this position?

Answer: No, the budget is not a reversal. The President has repeatedly stated in the campaign and after taking office his personal commitment to renewable energy. He also campaigned on the need for a National Energy Policy. That policy review is underway. In the budget we weeded out some R&D programs that had either accomplished their goals or were not performing as expected. But, in our amended budget, we protect several other programs like Hydrogen, Hydropower and High-Temperature Superconductivity, as launching points for new initiatives.

Dollars in thousands

FY2001	**FY2002**			**$Change**	**%Change**
Renewable Energy Resources					
$373,179	$237,477	$39,176 amendment	$276,653 Total	-$96,526	26%

Note: Of the $96 million reduction, $42 million is for congressionally directed projects. The comparable reduction is closer to 16%.

Question: If, as the President states, the country is facing a significant "energy crisis" that is impacting our ability to meet our Nation's increasing needs for electric power, home heating, and transportation fuel, then why at this critical time does your new Departmental Budget Request reduce funding for research and development of clean, domestic-based renewable energy resource technologies by $136 million?

Answer: Our ongoing operations will be evaluated against changes to national energy policy that follow from the Vice President's Energy Policy Development Group. While renewable energy technologies are not capable of replacing fossil fuels in the near-term, renewable energy will be part of the Nation's long-term energy supply. The Administration's budget request proposes increasing the performance of existing renewable research and development by winnowing out projects that are less promising and focusing on those next-generation areas that offer the greatest ability to tap or expand these new sources of energy. We need to give the taxpayer a better return on their investment in order to make sure America's energy needs over the next 20 years are met.

Question: How much has the Department of Energy invested to date in each renewable technology. For that investment, how much power is each technology generating and at what price?

Answer: During the past 20 years, the Department has invested $4,021,534,000 into renewable technologies. The table below reflects the investment by technology.

Wind Energy - $594,294,000
Geothermal - $758,947,000
Solar Energy - $2,158,735,000
(Concentrating Solar Power, Photovoltaics, and Solar Buildings)
Biomass/Biofuels - $852,733,000
Hydropower - $37,531,000

The table below provides most recent data on power generation for the renewable technologies. The hydropower and geothermal data is from the most recent renewable report of the Energy Information Administration (EIA). The other renewable data is from the National Renewable Energy Laboratory (NREL) Database. Since EIA relies upon REPIS , we use the primary data source in such circumstances. Column 2 indicates the amount of electricity in Megawatt-hours. Column 3 shows the range of prices. The costs per kilowatt-hour is extremely site specific for renewables, thus we present ranges based on the DOE program's site data and the methodology in a recent joint DOE/EPRI report .

Technology/Fuel	MWh1	Price (cent/kWh)
Hydropower	319,483,831	3-4
Wind	6,838,056	4-6
Biomass	54,431,136	7-8
Solar Thermal	930,312	12-14
Geothermal	16,812,610	5-8
Photovoltaics	210,240	17-25

Date Prepared: May 22, 2001 Energy Information Administration 2001, Renewable Energy Annual 2000, DOE/EIA-0603(2000) March 2001, Washington D.C.
\REPIS 1999, K. Porter, D. Trickett, L. Bird. The Renewable Electric Plant Information System, NREL. August, 2000. Electric Power Research Institute, Renewable Energy Technology Characterizations, EPRI TR -109496 Dec. 1997.

"Conventional" meaning it excludes about 19,000 MW of pumped hydroelectric a.k.a. pumped storage.
Does not include full capital costs as many of these were built by Federal PMAs. The cost of new hydro would be much higher.

Question: By measures such as cost per kilowatt-hour, the number of installed units in the U.S., the installed generation capacity in the U.S. and the number of vendors in the marketplace, where do the various renewable technologies fall along the path to commercialization?

Answer: All renewable technologies, even photovoltaics, involve some subsystems or components which are mature technologies and some which are relatively immature. Overall, hydroelectric power is the most mature, though research remains on technologies that minimize environmental impacts and on smaller systems. The steam (Rankine-cycle) turbines used to generate most biopower today also are quite mature, but work remains on improving the production of feedstocks expressly for biopower applications, on the handling of these biomass fuels, and on advanced high efficiency gasification, turbine, and fuel cell power generation systems. Of the so-called "new" renewables, wind now has the most installed capacity in the U.S., but, to fully realize the potential of wind power, research is needed on new turbine designs to extract power from winds with lower average speeds. Close behind wind is geothermal, which uses Rankine-cycle turbines to convert heat to electricity, but will benefit from research on improving techniques for extracting heat from the earth. Concentrating solar power which uses Rankine-cycle turbines in large applications will benefit from research in collector technology and heat transfer and collection, and, for distributed systems, from research on innovative heat engines. The "youngest" technology is photovoltaics, which was first demonstrated in the 1950s, and is now at the point where photovoltaic cells can be integrated with building components such as roofing, skylights, and windows, or in stand-alone applications. All of the research on the OPT portfolio focuses on those aspects of renewable technologies that have the greatest potential for cost reductions. The table below provides data, where available, on the measures requested: Cost per kilowatt-hour, installed electric capacity in megawatts (the third part of the question). The table below also shows installed worldwide capacity in MW and the number of vendors for each of the technologies.

Technology/Fuel	Price (cent/kWh)	MW in U.S. (End of 2000	# Vendors	MW worldwide (End of 2000)
Hydropower	3-4	79,511	N/A	683,000
Biomass	7-8	7,767	N/A	~20,000
Wind	4-6	2,550	N/A	17,300
Geothermal	5-8	2,898	N/A	~9,000
Photovoltaics	17-25	80	50+	1,200
Solar Thermal	12-14	354	N/A	380

Date Prepared: 5/18/01 Data on the number of installed units is not available. For all but PV, NREL and EIA collect installed capacity only. For PVs, which are mass-produced, we also have data on the number of MW (not units) produced in the U.S. and worldwide. In 2000 alone, for example, 287,700 kW of PV modules were produced worldwide, about 75,000 kW in the U.S. The number of vendors involved with each technology is difficult to define because most installed systems are integrated systems of components, incorporating the products of many suppliers. For example, for wind systems, the only truly unique component of the system is the blade. The other components are either adaptations of off-the-shelf products like gearboxes, generators, steel towers, etc. The concept of vendors is somewhat better-defined for PV, where we can cite the numbers of cell or module manufacturers. Because the question is attempting to understand technology maturity, we have provided worldwide installed capacity as an alternate measure of maturity.

"Conventional" meaning it excludes about 19,000 MW of pumped hydroelectric storage.
International Energy Annual 1999, DOE/EIA-0219(1999), February 2001, p 99.
OPT program estimate B the wide variety of biomass systems, both in technology and size, make such estimates difficult.

Question: During just the past five years, we've spent $1.5 billion on renewable energy R&D and another $5 billion on tax incentives. Yet the proportion of renewable energy in our total energy mix has remained the same, around 5%. Are there specific applications or sectors in which renewables are more likely to contribute?

Answer: The table on the following page indicates typical applications for various renewable energy technologies. While factors such as cost of energy, resource availability and end user needs will help determine the actual penetration and technology mix in these applications, there is the uses described for each technology in the table below are the most probable over the next two decades.

Technology/Fuel	Primary Electric or Energy Application
Hydropower	Hydropower can serve baseload, or constant electricity needs. It can also serve some small-scale, on-site power applications.
Wind	Wind can serve as an energy saver, reducing the need for conventional-fueled power plants. Wind can also serve baseload electricity needs when accompanied with electric storage or other hybrid applications, such as microturbines or fuel cells.
Biomass	Biomass can simultaneously serve heating and cooling energy needs, and electricity generation. Biopower is also useful in on-site applications where bio-resources are plentiful. In addition, bio-resources can be processed as a petroleum-based chemical replacement.
Biofuel	Biofuels can be processed into ethanol to be used as a transportation fuel additive (MTBE replacement) or used as the primary energy source in an ethanol/gasoline blend for specially designed engines.
Solar	Solar energy can be used to heat homes and pools. It can also be used to provide power at peak times, since solar energy production coincides with the peak load power demand curve. Lastly, in combination with electric storage and hybrid applications such as microturbines and fuel cells, solar power can provide on-site baseload power generation.
Geothermal	Geothermal energy can simultaneously serve heating and cooling energy needs, as well as baseload electricity in on-site applications where geothermal resources are available.

Question: Under present law, an income tax credit of 1.5 cents per kiloWatt-hour adjusted for inflation is allowed for the production of electricity from qualified wind facilities, "closed-loop" biomass facilities, and poultry waste farms. The current credit will expire on December 31, 2001. An extension of the credit has been included in a number of legislative proposals, including S. 2557, introduced in the 106th Congress by Senator Murkowski, which you cosponsored. Do you support an extension of the wind energy Production Tax Credit?

Answer: President Bush campaigned on the basis of expanded production of all energy supplies, and clearly supported an extension of this production tax credit. Without an unexpected change of direction as we develop national energy policy, I intend to support an extension. EE-3: Date: January 24, 2001.

Question: Your testimony states, "...the Vice President's National Energy Policy Development Group specifically highlights hydrogen as an important, next-generation technology, and recommends that R&D efforts be focused on integrating current programs regarding hydrogen, fuel cells, and distributed energy."

What is the scope of that you referred to, i.e. within your Office's programs, within the Department of Energy (DOE) across Federal government or between the Federal, state and local governments and the private sector?

Answer: During my testimony, I referred to those program actions primarily within the Office of Energy Efficiency and Renewable Energy (EERE), DOE. These programs are mission-driven, and therefore directed at distinct applications or end-use sectors. EERE's program activities are pursued, however, within the context of the broader portfolio of efforts across DOE, the Federal Government, States and the private sector. Whenever possible, EERE seeks to work either in collaboration or complementary with other organizations in order to achieve better results and to maximize the return for each Federal dollar invested. The development of low-cost hydrogen production processes and high-density hydrogen storage technologies are critical to the successful development and commercialization of fuel cells for transportation and distributed energy systems.

Within that context, EERE has recognized the importance of hydrogen as an interdisciplinary program. In the areas of distributed generation and proton exchange membrane (PEM) fuel cells, the Hydrogen Program supports research, development and engineering validation of reversible fuel cell systems that can co-produce hydrogen and electricity. The Distributed Energy Resources Program has the responsibility for reformat fuel cells to provide combined heat and power. Transportation application PEM fuel cells are also being developed by the Fuel Cells for Transportation Program for vehicles and buses. These programs coordinate their technology development when they are complementary, but conduct independent research when they are not. These first two programs are located within EERE's Office of Power Technologies and the latter within the Office of Transportation Technologies. Collectively, these sector offices have the responsibility to ensure coordination on all research and development of hydrogen and fuel cells applications that include co-sponsored solicitations.

All of the Department's efforts are coordinated via several mechanisms, including joint workshops, Annual Operating Plan reviews and the interagency's Fuel Cell Coordinating Council, which represents the Departments of Energy, Defense, Transportation, Commerce, National Air and Space Administration and the National Science Foundation, and the Interagency Advanced Power Group (IAPG), which includes all of the above agencies except the National Science Foundation.

Question: The Administration's Energy Plan recognizes that our country needs a diverse set of energy resources and I think there's bipartisan consensus in support of that view in the Congress. I think where the consensus may break down is how you go about ensuring our country has a diversity of energy sources. Certainly, we want to try incentives to encourage development of alternative energy sources, but incentives don't guarantee that these alternative energy sources are developed. What do you do besides incentives to guarantee that alternative energy sources are developed for the future? Should we have a portfolio standard to ensure that at least a minimum percentage of the energy mix comes from renewable sources.

Answer: Of the 13 recommendations for renewable and alternative energy contained in the President's National Energy Plan, five are for tax incentives. These five tax incentives are contained in the energy legislation, H.R. 4, which passed the U.S. House of Representatives this summer. Also found among the recommendations in the National Energy Plan are a mix of regulatory and research and development recommendations that will increase America's use of renewable and alternative sources. A key recommendation is for the Secretary of Energy to conduct a review of Research and development programs. We hope to complete that review shortly and submit it to the Office of Management and Budget (OMB), thus allowing the Administration to work with the Department of Energy (DOE) to prioritize DOE's programs and clarify the linkages of its research and development programs with real world outcomes. Past DOE-sponsored research and development has contributed significantly to greater use of alternative energy. We anticipate that our review will allow an even greater use of alternative energy through focused R&D that leads to accelerated technology results.

On the question of whether we should have a renewable portfolio standard, many states have already chosen to do so. In fact, DOE estimates that existing state laws and policies, if their "guarantees" are maintained, will result in more than a doubling of non-hydro renewables by 2012. The 8,400 MW of additional capacity is from 5,500 MW of state purchase obligations (including renewable portfolio standards) and 2,900 MW estimated to potentially be developed through system-benefits charges and other renewable energy funds. The Secretary of Energy is charged by the National Energy Policy to propose comprehensive electricity legislation that, among other things, promotes renewable energy. A number of options are under consideration to achieve that goal, and no option has been ruled out.

Question: Regarding Coordination with EPA on Emissions Rule-making, and Whether or not DOE should encourage EPA to look at the broader picture of rule-making on emissions instead of single-purpose rule-making on individual emissions.

Answer: Yes. The DOE continues to encourage the Environmental Protection Agency (EPA) to adopt a more integrated approach in its rule-making regarding the control of pollutants. Our encouragement is not limited to ambient air pollutants.

The Office of Energy Efficiency and Renewable Energy is a natural agent for encouraging EPA to adopt a systems approach to problem-solving, since this is a fundamental principle behind our research, development, and deployment programs. When our efficiency programs succeed in saving energy, they simultaneously succeed in reducing a wide spectrum of pollutants and greenhouse gases. So it is natural that our understanding of the value and benefits of using an integrated multi-pollutant approach should stem from our experience. We are committed to approaches and technologies that prevent pollution over a broad range of individual pollutants, including air pollutants, water pollutants and solid waste as well. As you know, we have no authority over EPA, so we are placed in a consultative role to encourage them.

Nonetheless, the DOE Office of Energy Efficiency and Renewable Energy works closely with EPA's Office of Air and Radiation, as well as the commissioners of state environmental programs, to encourage development of State Implementation Plans that use energy efficiency as a strategy of first choice in efforts to achieve clean air goals. Using existing authorities at both the state and national scale, significant multiple benefits may be gained for the economy and the environment. For example, an analysis of federal, state and local refrigerator standards over the period 1975 to 1993 provided annual energy reductions in 1999 equivalent to closing 25 large electric powerplants (1000 MW each), annual emission reductions in 1999 of taking 25 million cars off the road, and all of this at a net annual energy cost savings of $7 Billion.

In additional to these creative and voluntary efforts, reauthorization of the current 1990 Amendments to the Clean Air Act provides the Congress with a unique opportunity to further encourage and enable EPA to utilize comprehensive approaches in solving pollution problems. It is our view that the integrated approach is highly preferable to an approach that utilizes a series of single-purpose, single-pollutant remedies.

One of our most successful programs to demonstrate the value of an integrated approach was developed and operated jointly with EPA for several years in the early 1990s. This program, National Industrial Competitiveness through Efficiency, Environment and Economics (NICE3) is a competitive matching grant program that convincingly demonstrates the value of thoughtful design, using a comprehensively integrated approach to solve environmental problems. This program clearly shows the value and multiple benefits of solutions based on good design. While requiring creativity, designs for comprehensive solutions reduce air, water and land pollution of all sorts, with one stroke. Unfortunately, after successfully co-sponsoring this competitive grant program with DOE for a number of years, EPA withdrew their support of the program in the mid-1990s. DOE continues to successfully operate this program within the EERE Office of Industrial Technologies.

Recently, our efforts to encourage comprehensively integrated approaches were strengthened by the National Research Council (NRC) with its recommendation for closer coordination between the Department of Energy and the Environment al Protection Agency -- with regard to the relationship between emission standards and research on emission reductions. This recommendation descends directly from the NRC review of the Partnership for a New Generation of Vehicles (PNGV) program. Since research and development of emission control technologies takes time, a predictable regulatory environment is helpful to the R&D enterprise.

To help ensure coordination with PNGV, EPA and DOE jointly participate as members of the PNGV Steering Group. Each agency is represented on various PNGV technical teams. DOE shares its emission-related research with EPA, and reviews EPA's vehicle and vehicle-fuel-related rule-makings. In the PNGV program, the Federal Government is represented by the Departments of Commerce, Defense, Energy, and Transportation, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation.

Often offering comments, DOE interacts with (sometimes reacts to) EPA on rule-makings and we usually stress the value of taking an integrated approach:

On March 2, 2000, Mark Mazur of the Department of Energy's Policy Office testified before the House Committee on Commerce, Subcommittee on Health and the Environment on the issue of MTBE in reformulated gasoline. In that testimony, a number of options were offered, short of a ban of MTBE in gasoline, that would nonetheless reduce contamination of water supplies by MTBE. These options were offered based on an understanding of the broader context and opportunities throughout the “life-cycle” of MTBE use.

In a letter from Deputy Secretary of Energy T.J. Glauthier to EPA Administrator Browner dated July 31, 1999, the Department commented in response to EPA's Notice of Proposed Rulemaking on Clean Air Act “Tier 2&” vehicle emission standards and standards for low sulfur gasoline. That letter discusses regulatory uncertainties and their impact on investment decisions. A theme of the comments offered in that letter is that a better understanding of the context in which the refining system operates will provide opportunities for EPA to smooth out potential bumps in implementation.

The DOE recently asked the National Petroleum Council (NPC), a federal advisory committee to the Secretary of Energy, to examine issues related to environmental is sues and petroleum product markets. NPC is finishing a study, which addresses the cumulative impacts of several product quality regulations, including changing the role of oxygenates in reformulated gasoline, on refinery viability and product deliverability. A Draft Report, dated March 30, 2000, assesses Government policies and actions that will affect both the petroleum product supply and the continuing viability of U.S. refineries. Secretary of Energy Federico Pena requested this study in a letter to the NPC dated June 30, 1998, as a means of obtaining a clearing picture of the refining landscape and the systems context in which the refiners operate.

Like most individuals, we have found that industry prefers a level of certainty about what may be required of them in the future; and they prefer freedom from sudden shocks to their operations. Loosely knitted single-purpose rule-making on individual emissions provide neither. A comprehensive design approach provides both.

Question: What has been achieved?

Answer: Throughout the decade of the 1990s, the Office of Energy Efficiency and Renewable Energy (EERE) invested $712 million in projects described in the success stories document. Additional costs have been incurred by the numerous industrial, university, utility, and public-sector collaborators that have also invested in the commercialization and deployment of these technologies.

More than 5,500 trillion Btu of energy has been saved from equipment implemented to date as a result of these activities. Of this total, 5,050 trillion Btu of savings is from EERE R&D successes, and almost 500 trillion Btu is from EERE field verification, deployment, and outreach successes. These savings are enough to meet the energy needs of al l of the citizens, businesses, and industries located in the states of New York, Connecticut, and New Mexico, for one year. EERE R&D and field verification, deployment, and outreach programs have also replaced another 1,700 trillion Btu of fossil fuels with renewable alternatives. This is equivalent to running all of the cars registered in the states of California, Florida, Mississippi, and West Virginia on ethanol rather than gasoline, for one year. Significant reductions in carbon emissions from these activities, 102 million metric tons, have resulted from these reductions in burning fossil fuels.

Question: DOE requests over a billion dollars for the President's Climate Change Technology Initiative -- $100 million in new spending just for Solar Renewables. The Renewable Indian Energy Resources Program, which is part of the Solar and Renewable Energy Program, has been particularly successful in leveraging electrical infrastructure development by and for Native Americans in my State and in other States. As a result of this program, renewable-fuels generation projects and associated regional electric interties have been constructed where they otherwise would not have been. The benefits are not just rural economic development and better electric rates for individual rural consumers, but also reduced dependence on oil and cleaner air. When it was created about four years ago, the program was authorized and funded at $10 million annually. In the past several years, funding levels have fallen to $4 million. Yet, DOE has asked for no funding for the Renewable Indian Energy Resources Program in FY 1999, despite the high cost-effectiveness of this program. I want to urge you to continue to support this small but valuable program. Why? There is no explanation in the budget documents. If no funds are requested because the reauthorization legislation is still pending, please provide for the record citations for all authorities for this program and a list of all currently unauthorized programs for which DOE has requested funding.

Answer: The decision not to seek appropriations for this line item in FY 1999 was not based upon the status of pending reauthorization legislation. Rather, the Department intends to combine the best aspects of two efforts -- the Renewable Indian Energy Resources program and the Federal Buildings/Remote Power Initiative -- into a single, competitive, nation-wide program that is not restricted by either the type of renewable technology or geographic location. The FY 1999 request for Solar Program Support includes $10M for a new Competitive Solicitation that would provide such flexibility. Additionally, we share your concerns for addressing the needs of our Native Americans for clean, reliable, cost-competitive sources of electricity. It is anticipated that up to $3M of the proposed $10M Competitive Solicitation will be reserved for renewable projects that directly benefit Native Americans.

The new initiative, if funded, will be structured as a five-year, cost-shared, highly leveraged partnership ($10 million per year Federal investment leveraging considerably more non-Federal funds) for identification and deployment of innovative renewable energy and hybrid renewable technology applications. The Department would offer technical and financial support of new renewable energy projects with up to 70% private sector cost share aimed at projects appropriate for a restructured electric power industry.

Please be assured that DOE will meet its current obligations with regard to ongoing Renewable Indian Energy Resource Program activities. These include:

- **Power Creek Hydroelectric Project** in Cordova, AK The grant is in place. The project received its license from the Federal Energy Regulatory Commission on December 24, 1997. Final design activities are underway.

- **Upper Lynn Canal Regional Electric Project** in Skagway Bay, AK Funding has been provided to the Idaho Operations Office for grants and cooperative agreements for construction of this electrical intertie.

- **Old Harbor Hydroelectric Project** in Village of Old Harbor, AK. Funding has been provided to the Idaho Operations Office for grants and cooperative agreements.

- **Scammon Bay Hydroelectric Feasibility Study Funding** has been provided to the Idaho Operations Office for a study of the potential for locating a hydroelectric facility at this location.

Additionally, pursuant to EPACT Title XXVI, 30 grants for Native American energy projects were awarded during FY 1994 and FY 1995. These 30 Title XXIV grants involved hydro-electric feasibility studies, identification of areas to promote wind farm development, deployment of utility-grade wind turbines, etc., involving 29 tribes within a 13-state area. Twenty-six of the initial 30 grants are currently in close out.

The four remaining Title XXVI grants are:

- Jicarilla Apache Tribe

The Jicarilla Apache Tribe is located in Northwestern New Mexico.
There are approximately 3,000 people residing on the Reservation, which is rich in natural gas, hydro, solar and wind resources. In FY 1995, the Tribe obtained an EPACT Title XXVI grant from DOE/EERE to carry out a feasibility study on developing hydroelectricity and other renewable energy resources on the Reservation. The study concluded that it was feasible to obtain 16.5 MW of renewable energy capacity using photovoltaics, wind turbines and a hydroelectric facility.

In FY 1997 the Tribe submitted an unsolicited proposal to EERE's Office of Utility Technologies, seeking technical information and guidance, as well as financial support for development of an implementation plan for its renewable projects. Based on the background and quality of the proposal, as well as the potential for replication of the Jicarilla planning process with other Tribes, $200,000 was provided in FY 1997 and an additional $200,000 in FY 1998. Rural applications, such as Native American tribal lands, will have limited choices under utility restructuring. Renewable energy technologies are cost-effective choices for many of these markets.

- Laguna Pueblo

The Laguna Pueblo grant was funded in FY 1994. The project's objectives were to produce a feasibility study of manufacturing photovoltaics (PV) modules at the Laguna Industries electrical assembly plant. The grant was given a no-cost extension (which is expected to expire on September 28, 1998) so that the Pueblo could pursue the possibility of manufacturing 5 MW of PV modules for a PV power plant to be constructed by Public Service Co. of New Mexico near Albuquerque.

- Mohegan Tribe

The Mohegan Tribe grant was awarded in FY 1995. The project's objective was to produce an analysis of energy efficiency and renewable energy applications for a proposed tribal destination resort and casino in a former nuclear submarine engine assembly plant. The grant was extended to allow the Tribe to investigate the possibility of incorporating energy efficiency and renewable energy features into their proposed housing project for tribal elders,
to be constructed on property adjacent to their casino. This no-cost extension is expected to expire on September 28, 1998.

- Crow Tribe - Montana

The Crow Tribe grant was funded in FY 1994. The Crow Tribe of southeast Montana owns the rights to a large amount of coal, which is currently mined by an outside company under a royalty agreement. The tribe, acting through its wholly owned Crow Energy Corporation, is performing a feasibility study of a 260 MW mine-mouth co-generation plant, the waste heat from which could be used in an industrial plant. The targeted application is a fuel ethanol manufacturing facility, which could provide a market for locally produced grain crops as well as employment for tribal members. The preliminary project report concludes that the power plant could produce electricity in 2002 at a busbar cost of about 3.25 c/kwh, which will be between the current short-term spot market price of 2-2.5 c/kwh and the average local utility rate of 4-5 c/kwh. This

Question: Given that most emissions sources produce more than one undesirable pollutant, does it strike you as sensible that our regulatory regime is centered upon a seemingly endless series of single-purpose rule-makings on individual emissions (Sox, sulfur, particulates)?

Answer: The Department of Energy does encourage the Environmental Protection Agency (EPA) to adopt a more integrated approach in its rule-makings regarding the control of pollutants. DOE also works closely with EPA's Office of Air and Radiation, as well as the commissioners of state environmental programs, on non-regulatory opportunities to approach energy and environmental issues on this broader basis, such as by encouraging development of State Implementation Plans that use energy efficiency as a strategy of choice in efforts to achieve clean air goals.

The Department's efforts to encourage comprehensively integrated approaches were strengthened by the National Research Council (NRC) with its recommendation for closer coordination between the Department of Energy and the Environmental Protection Agency -- with regard to the relationship between emission standards and research on emission reductions. This recommendation descends directly from the NRC report, Review of the Partnership for a New Generation of Vehicles (PNGV) program, 1999.

As an example of this type of coordination with the Environmental Protection Agency on the PNGV program, PNGV, EPA and DOE jointly participate as members of the PNGV Steering Group. Each agency is represented on various PNGV technical teams. DOE shares its emission-related research with EPA, and reviews EPA's vehicle and vehicle-fuel-related rule-makings. In the PNGV program, the Federal Government is represented by the Departments of Commerce, Defense, Energy, and Transportation, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation. Additionally, the Department provided comments in response to EPA's Notice of Proposed Rulemaking on Clean Air Act "Tier" vehicle emission standards and standards for low sulfur gasoline. That letter discusses regulatory uncertainties and their impact on investment decisions.

To broaden our understanding of energy and environmental interactions, DOE recently asked the National Petroleum Council (NPC), a federal advisory committee to the Secretary of Energy, to examine issues related to environmental issues and petroleum product markets. NPC is finishing a study that addresses the cumulative impacts of several product quality regulations, including changing the role of oxygenates in reformulated gasoline, on refinery viability and product deliverability. A Draft Report, dated March 30, 2000, assesses Government policies and actions that will affect both the petroleum product supply and the continuing viability of U.S. refineries. Secretary of Energy Federico Pena requested this study in a letter to the NPC dated June 30, 1998, as a means of obtaining a clearer picture of the refining landscape and the systems context in which the refiners operate

Question: For the record, please provide a breakout of funding included in your request for the bio-energy/bio-products initiative, and for each project, include funding information for fiscal year 2001.

Answer: The fiscal year 2001 budget request includes $26 million in funds for joint activities under the Biobased Products and Bioenergy Initiative. These funds are in four program areas and under two separate appropriation accounts. Under Energy and Water Development, the Department is requesting $11 million within the Biopower Program and $7 million within the Biofuels Program. Under the Interior appropriations, the Department is requesting $5 million within the Agriculture Vision and $3 million within the Forest and Paper Products Vision. The Department plans to apply these funds to an integrated solicitation supporting the concept of a bio-refinery. This effort is designed to demonstrate whether the combination of biomass technologies in a single facility can improve the economics, and thereby accelerate the commercial introduction of bioproducts and bioenergy.

Biopower

Question: What funds are included for this initiative for programs under the jurisdiction of the Energy and Water Appropriations bill?

Answer: While the Department views all funds appropriated for the Biomass/Biofuels Energy Systems as supporting the Biobased Products and Bioenergy Initiative, specifically $18 million is requested for joint activities supporting bio-refinery technologies, $11 million under Power Systems and $7 million under Transportation.

Question: What other agencies of government are participating in this initiative and what funds are included in each of their budgets?

Answer: Per Executive Order 13134, the Department of Energy (DOE) and the U.S. Department of Agriculture (USDA) have established the Interagency Council on Biobased Products and Bioenergy. This Council is comprised of senior representatives from the following agencies: Commerce, Interior, Treasury, the Environmental Protection Agency, the Office of Management and Budget, the Assistant to the President for Science and Technology, the National Science Foundation, and the Federal Environmental Executive. The two agencies that are leading this interagency effort are DOE and USDA. USDA is currently the only other agency requesting new funding for this Initiative. The USDA fiscal year 2001 request is up $96 million.

Question: What is the bioenergy/bioproducts initiative and what role do the industry programs play in this initiative?

Answer: The Initiative is a national partnership between the federal government and industry to develop a more comprehensive and coordinated approach toward the development and use of biomass for power, fuels, and chemical products. The Initiative will build on existing Department programs in biofuels for transportation, biopower for utilities, and bioproducts, with the intention to help bring about a much more strongly integrated bioenergy industry. Input from other Federal agencies, as well as major private sector company leaders, has been obtained to help develop a vision for the bioenergy industry. The Federal government will continue to work with industry on the planning and implementation of programs which support the development of renewable fuels and products for the transportation, utilities and industrial sectors. Within the Office of Energy Efficiency and Renewable Energy, the bioenergy initiative is coordinated across the Office of Transportation Technologies, the Office of Power Technologies, and Office of Industrial Technologies. Within the industry programs, the Agriculture Vision and the Pulp and Paper Products Vision are requesting funds and are actively involved in the planning and implementation of projects designed to integrate biomass-based technologies.

Question: What is the Administration as a whole doing to coordinate its environmental and energy policies?

Answer: Several promote ongoing interagency coordination of environmental and energy policies, including White House task forces (such as the White House Climate Change Task Force) and interagency working groups. In each case, representatives from all of the relevant agencies are included along with White House representatives. Multi-agency budget crosscuts (such as for the Bioenergy and Bioproducts Initiative) are prepared by the Office of Management and Budget (OMB) with each relevant agency to establish the overall funding for multi-agency efforts.

Periodic, but nonetheless important, forms of multi-agency cooperation are also prevalent, including consultation during the rulemaking process (such as the consultation with EPA in the development of the commercial and residential building codes for Federal buildings [10 CFR 434 and 435] and joint sponsorship of studies or conferences exploring particularly complex energy-environmental interactions. Agencies may, of course, formally comment to one another on particular policies or rulemakings of interest and key policy-related documents go through a formal interagency review process. In the case of the budget and rulemakings, OMB reviews agency proposals, providing an additional level of coordination.

Energy and environmental issues interact in complex, and sometimes surprising ways. While these mechanisms provide opportunities to coordinate energy and environmental policies, they will not always work perfectly, especially where important connections between the two are not well understood scientifically or where interactions may be indirect and therefore the need f or coordination may not be immediately evident .

Question: How is the Department supporting Biomass Technologies in this budget?

Answer: With the Budget Amendment recently submitted, Biomass technologies within the Energy Efficiency and Renewable Energy program are supported near the FY01 level. In addition, this budget increases Office of Science funding by $30 million for Biomass basic research.

- Biomass offers promising options for both power and fuels requirements that are environmentally sensitive and can provide an economic stimulus to rural areas.
- In Biopower, which provides 3% of our primary energy, we support R&D to co-fire biomass with fossil fuels such as coal and natural gas; small modular biopower systems; and advanced biomass gasification.
- In Biofuels we support R&D and demonstration in Ethanol Production, Renewable Diesel Alternatives, Feedstock Production, Regional Biomass Energy Program, and Integrated Bioenergy Research.
- In both budgets we have requested $5 million total for integrated R&D on bioenergy and biobased products to support the biomass R&D Act of 2000.

Dollars in thousands

	FY2001	FY2002	$Change	%Change
Biomass Technologies	$86,268	$80,500		
Budget Amendment		$1,455 amendment		
Total, Biomass		$81,955	$4,313	- 5.0%

Distributed Energy Resources

Question: I am very interested in your initiative to capitalize on combined heat and power in buildings and industry resulting from distributed generation and utility restructuring. However, I hope the importance of integrating gas cooling technologies in buildings and industrial processes is not lost in the reorganization. What are you doing to provide continuing support and effective integration of these technologies?

Answer: The Distributed Energy Research task force will provide a more cohesive structure to integrate the industrial and buildings combined heating and power (CHP) programs. The buildings cooling heating and power program will still focus on integrating innovative CHP systems, such as incorporation of microturbines with absorption chillers, or fuel cells with desiccant dehumidification systems. It is imperative that coordination occurs among advanced distributed generation systems development, such as the microturbines and advanced reciprocating engine programs, interconnection, buildings codes and standards building technologies, such as fuel cells, absorption chillers.

Geothermal

Question: I would like you to provide your views on the effort to develop a geothermal energy project on Federal lands in the Glass Mountain area near the southern Oregon border. The entire process has literally dragged on for decades. It involved getting the Bonneville Power Administration to make a commitment to buy energy in the project and the Forest Service and BLM were also involved in a whole series of environmental reviews. Getting each of these agencies on board has involved years of reviews and delays on decisions about the project. Last year, then Energy Secretary Richardson called it "an important test of the future viability of geothermal energy in the West." If that's the case, then I think you would have to give a grade of "needs improvement" on that test. What can this Administration do to promote the development of geothermal and other renewable energy sources on Federal land in an environmentally responsible way?

Answer: The Department of Energy supports increasing the use of geothermal energy in the West and has specifically gone on record in support of both the Fourmile Hill and the Telephone Flat projects in the Medicine Lake Highlands near Glass Mountain. While the Department was a participating Federal agency in the process of preparing an Environmental Impact Statements for both of those projects, we did not have the authority or responsibility for issuing either Record of Decision. That responsibility lay jointly with the U.S. Bureau of Land Management and the U.S. Forest Service. Both projects underwent considerable scrutiny during the review process, which was instrumental in helping those agencies formulate mitigation plans to minimize potential impacts from the projects. In the case of Telephone Flat, the impacts were judged to be unacceptable, even with mitigation, and the project was denied. However, the Fourmile Hill project was authorized to proceed under rather stringent conditions.

In May of this year, the National Energy Policy Development (NEPD) Group issued its recommendations for reliable, affordable, and environmentally sound energy for America's future. An entire chapter was devoted to increasing use of renewable and alternative energy. It including the following two recommendations relevant to leasing of Federal land for geothermal development:

- the NEPD Group recommends that the President direct the Secretaries of the Interior and Energy to re-evaluate access limitations to Federal lands in order to increase renewable energy production, such as biomass, wind, geothermal, and solar; and

- the NEPD Group recommends that the President direct the Secretary of the Interior to determine ways to reduce the delays in geothermal lease processing as part of the permitting review process;

The Department of Energy is working closely with the Departments of the Interior and Agriculture to implement these recommendations and help increase the use of renewables, specifically including geothermal energy, on public lands.

Question: The Department has an opportunity to help fund much needed baseload energy in California. Can the Department contribute to recharging The Geysers by assisting in supplying reclaimed water from Santa Rosa?

Answer: In the past, the Department supported a feasibility study of the geothermal pipeline alternative that led to the selection of this wastewater disposal option by the City of Santa Rosa. The Department has also worked closely with the geothermal industry in a research program to understand the drop in reservoir pressure and productivity at The Geysers. This research figured prominently in the subsequent success of the Lake County pipeline project. At this stage, we view the Santa Rosa Geysers Recharge Project as a public works water project rather than a research and development effort. We believe the City of Santa Rosa and the geothermal industry are fully capable of successfully developing the project without further assistance from the Department of Energy.

Question: The hearing acknowledged the need to develop water injection for geothermal resources that lack water to transfer their full heat potential. This technology is currently needed to address different heat and corrosion reservoir conditions within The Geysers and will eventually be needed at other reservoirs. Besides funding for the Lake County project and a small amount of initial funding for the Santa Rosa project, what research and development has the Department funded on water injection? Why has the Enhanced geothermal Systems activity been eliminated from the proposed 2002 budget?

Answer: The Department considers injection as an essential element of a successful geothermal project. The injection of water, including the used brines from geothermal reservoirs, helps maintain the productivity of the reservoir and prolong its lifetime. We have conducted broad-ranging research related to injection, which included improvements to reservoir simulators and the use of tracers that can be used to locate injection wells for proper reservoir management. In particular, we worked with the developer of the Dixie Valley (NV) geothermal resource to gain a much improved understanding of how fluids move through the reservoir from injection wells to production wells. The developer has used that information to implement an injection program that includes augmenting used brines with water from a shallow aquifer. Our work on injection has already improved the productivity of the geothermal fields at The Geysers and Dixie Valley and promises to have positive impacts at many other fields as well.

In concluding our efforts in Enhanced Geothermal Systems, the Department is placing higher priority on other activities within the Geothermal Program that have been identified by industry as critical for overcoming the chief technical barriers to greater near-term use of geothermal energy. These activities include developing technologies for finding and characterizing geothermal resources and reducing the cost of drilling wells.

Hydrogen

Question: What is the focus of the Department's Hydrogen Research program?

Answer: The amended budget maintains level funding for hydrogen research because it has significant long-term potential in both the transportation and utility sectors. The use of hydrogen fuel produced from biomass, waste, and other renewable feedstocks will result in emissions of only steam.

We will work on developing suitable production, storage and use technologies, including the infrastructure that would support this new fuel in wide usage. The key cost drivers right now are production (still 2-3 times the cost of natural gas), and storage. The program plans to validate several reversible fuel cell systems by 2005, which reduce the capital cost and resultant electrical generation cost.

By 2010, we believe we be able to have hydrogen refueling stations with a hydrogen cost competitive with today's gasoline fuel prices on a cost-per-mile basis when used in a hydrogen fuel cell vehicle.

Dollars in thousands

	FY2001	FY2002	$Change	%Change
Hydrogen Research	$26,881	$13,900		
		$12,981 amendment		
		$26,881	0	0

Definition: "Reversible" Fuel Cell – Like a "rechargeable" battery, a "reversible" fuel cell can be used to produce electricity from the fuels it is fed, or be reversed to produce the fuels when it is fed with electricity.

Question: Why are advanced hydrogen production and storage technologies important?

Answer: Hydrogen can be used both in stationary applications that have benefits for the power sector and in mobile applications where it can displace petroleum. Fuel cells, because of their modularity and low or zero emissions, offer significant opportunities for distributed generation, which can place new generating sources near load centers. This placement means that the new generating capacity does not add to the load on major transmission lines and switching or distribution centers, many of which are already operating at or near their maximum capacity. Economical technologies for producing pure hydrogen will allow fuel cells to operate more efficiently than they do on the hydrogen-rich (but not pure) gas that current-generation reformers provide, thus boosting their output while lowering their emissions of regulated pollutants to essentially zero.

If the hydrogen is produced from renewable fuel sources rather than natural gas or coal, then the fuel-cell systems become net-zero greenhouse gas power systems as well. If "reversible" fuel cells and bulk hydrogen storage can be produced economically, they can provide significant benefits to utilities for load-leveling, by running "in reverse" to generate hydrogen from water and electricity when electric demand is low, and then generating electricity from the stored hydrogen when electric demand is high.

Dollars in thousands

	FY2001	FY2002	$Change	%Change
Hydrogen	$26,881	$13,900		
		$12,981 amendment		
		$26,881	0	0%

Question: How does the U.S. Federally funded hydrogen R&D programs compare with other countries that are committed to a hydrogen-based energy future?

Answer: The U.S. Federally funded R&D program is the largest national effort at $31,000,000 for FY 2002. The Hydrogen Program includes research and development activities for production, storage and utilization and technology validation efforts that include hydrogen/renewable systems, hydrogen refueling stations and power park projects.

Many of the larger-scale hydrogen demonstration projects taking place in Europe are part of the European Union Framework Programmes. Hydrogen is integral in several key action areas, particularly fuel cells. During 1998-2002, $25 million (of which $11 million is for transport projects and $14 million is for stationary electricity generation) is being provided by the EU and an additional $65 million is provided by industry. A total of $45 million is being provided for 30 fuel cell buses that will be demonstrated in 10 European cities.

Of the national programs, Japan's is the next largest in scope and funding to the U.S. program. The program is centered around a fully integrated hydrogen society. The portfolio of technologies under development mirror the range of technology currently planned for the U.S. DOE Hydrogen Program: FY99 funding was approximately $13 million. Total funding for Phase II (1998 - 2003) is planned for $81 million. Japanese industry also supports a number of large hydrogen research efforts, particularly in the automotive arena.

Canada combines Hydrogen and Fuel Cells into a single program that is approximately $4 million per year. The program is geared toward technologies with short-to-medium term commercial potential. Several Canadian companies, such as Ballard and Stuart Energy are world leaders in hydrogen technologies and have received a great deal of external funding from other governments and industry. For example, Ford contributed $400 million to Ballard's Fuel Cell development program.

Germany has a unique position with regard to hydrogen R&D. Today, the bulk of the research effort resides with companies like BMW and Daimler and with regional governments, particularly Bavaria. The national government continues to support some development efforts, but at a vastly reduced level (approximately $1 million).

Switzerland's Hydrogen Energy and Technology Program supports hydrogen as an important secondary energy carrier and chemical commodity that is funded at approximately $3.8 million. Private funding is around $300,000 United States Dollars (USD) per year.

Norway's funding is on the order of $600,000 annually. The bulk of Norway's hydrogen development efforts comes from industry. Currently, approximately $2.5 million is being spent on hydrogen demonstration projects and this number is increasing. Electrolysis and fuel cells receive the bulk of the government support.

The Netherlands funds an estimated $2 million per year toward hydrogen-specific technologies. Sweden is funding more than $5 million in hydrogen or hydrogen-related research, including fuel cells. The Swedish portfolio includes renewable production, including direct water splitting (both electrolysis and biological), solid-state storage materials and utilization.

Question: H.R. 2174, the Robert S. Walker and George E. Brown, Jr. Hydrogen Energy Act of 2001, was drafted with such integration in mind. Would you please discuss, and provide written recommendations, as to how the bill may facilitate the recommended integration of hydrogen programs?

Answer: The programs within the Office Energy Efficiency and Renewable Energy (EERE) are coordinating their activities to achieve the performance goals outlined in The President's National Energy Policy (NEP). This coordination role was established per Section 106 of the Matsunaga Hydrogen Research, Development and Demonstration Act of 1990, (P. L. 101- 566), and amended in Section 105 of the Hydrogen Future Act of 1996, (P. L. 104-271). The Department implemented this coordination process at the time it assigned responsibility for its Hydrogen Program to EERE in June 1991. Through the Deputy Assistant Secretary, each EERE sector office's cross-cutting technology programs are directed to meet regularly to discuss accomplishments, plan collaborative projects and meetings, and present their programs to the Hydrogen Technical Advisory Panel.

Crosscutting technology programs within other agencies are more difficult to coordinate. The Department has recently completed an investigation of all Federally funded hydrogen projects using the Rand database. Total funding for all hydrogen and hydrogen related research is approximately $120 million per year. The agencies funding projects include the Department of Agriculture, Commerce, Defense, Energy and Transportation; however, most of this research is mission oriented and not specific to the application of hydrogen as an energy system.

The Department's recommendation to improve this coordination role would be to assign the Assistant Secretary for EERE the responsibility and authority to request information on each agency's hydrogen and hydrogen related research and development. The Assistant Secretary for EERE, in consultation with members of his staff, would meet with other agency heads and Administration personnel to draft a comprehensive coordination plan that could be presented to Congress.

Question: Later in your testimony you state, "The Administration believes a coordinated interagency effort will strengthen our ability to move toward commercial use of hydrogen.." Is this the same or a different approach from the program integration mentioned earlier in your testimony? How would such an interagency approach be structured? Does an appropriate model currently exist? Is legislation required? Section 7 of H.R. 2174, the Robert S. Walker and George E. Brown Jr. Hydrogen Energy Act of 2001 provides that the Secretary of Energy shall "...develop, with other Federal agencies as appropriate and industry, an information exchange program to improve technology transfer for hydrogen production, storage, transportation, and use, which may consist of workshops, publications, conferences, and database for the use by public and private sectors..." Is this a sufficient interagency effort? If not, please provide comments on how to strengthen this language.

Answer: The DOE would recommend an approach that involves all Cabinet level members of this Administration, who would meet and discuss options for the best method(s) to integrate and report on all interagency activities related to hydrogen research. After these meetings, the Department of Energy would prepare a comprehensive plan to Congress on its recommendations.

The Department has several examples of interagency agreements dealing with technologies. However, none are as extensive as that which would be required to integrate efforts on all fuel cells and hydrogen technologies.

The programs within EERE support a number of outreach activities to transfer technology information to the private sector, per Section 105 of the Hydrogen Future Act of 1996. These include competitive support for domestic and international conferences; peer review meetings using industry members as technical reviewers; websites for specific technologies; publishing of technical papers in peer reviewed journals; and the production of brochures, compact discs, and videos that illustrate recent accomplishments.

Other agencies use their own internal policies for dissemination of information. We would propose that this topic be discussed at the interagency meeting identified above, and be included in the comprehensive coordination plan to be presented to Congress.

Question: As you are aware this Committee's past authorizations for hydrogen R&D have greatly exceeded the actual appropriations (appropriations have been approximately 50 percent of authorization). H.R. 2174, the Robert S. Walker and George E. Grown, Jr. Hydrogen Energy Act of 2001, significantly increases authorization for appropriation in each fiscal year 2002 through 2006. If the appropriators meet these authorized levels, will the U.S. Department of Energy (DOE) and industry programs be able to respond in a productive, meaningful and coherent way?

Answer: Hydrogen can be produced in many ways and from diverse domestic resources. As such, hydrogen is an ample clean energy choice that also offers a secure energy option for the nation. The Hydrogen Program has been supporting industry activities in the low-cost production of hydrogen, low-weight hydrogen storage systems and end-use systems, including the development of codes and standards. In recognition of hydrogen's potential, there has also been significant industry investment in fuel cells for stationary power generation, and by the automobile and oil companies in hydrogen fuel cell vehicles and hydrogen infrastructure.

There are still significant remaining issues that are associated with the cost and durability of fuel cells, the establishment of the hydrogen infrastructure, advanced hydrogen storage systems, and the acceptance of the codes and standards for hydrogen systems. The industry is proceeding with test programs for stationary fuel cells and fuel-cell vehicles and buses. There is a need for increased Federal funding to conduct research and development necessary to achieve the cost and performance goals for the production, storage and utilization of hydrogen, and the integration of fuel cell systems into Federal and State facilities. Thus, Federal and State governments will be early users of hydrogen systems to support the significant industry investments being made.

The President's National Energy Policy (NEP) is a coherent plan that specifically recognizes the importance of hydrogen to the future of the nation. The FY 2003 budget submission for the Hydrogen Program is being formulated to meet the objectives of the NEP and to address the industry's increasing needs.

Solar

Question: Why is DOE ending its support for the Concentrating Solar Power program?

Answer: Due to the reduced size of the budget for DOE, and competing priorities, we decided to reduce funding for this program. Since its inception in 1975, the Concentrating Solar Power program (formerly called the Solar Thermal program) has received approximately $1.0 Billion and much of the technology developed under this program is commercially available and in use around the world. This makes federal funding much less critical now then in the past. In addition, the National Research Council issued a report critical of further federal funding. The budget does contain almost $2 million for close-out costs.

Dollars in thousands

	FY2001	**FY2002**	**$Change**	**%Change**
Concentrating Solar Power	$13,710	$1,932	-$11,778	86%

Definition: "Concentrating Solar Power" – This program has funded demonstrations using systems of mirrors to focus solar ray on materials that were heated to transfer this heat to water or some other fluid to run turbines, etc.

Question: Can solar energy provide all the energy needed by a home?

Answer: It can be done. In niche domestic markets it is being done today. In global markets with low electricity needs, no central power and significantly higher energy costs it can be cost effective. A net-zero energy home, which combines energy efficiency and renewable power is one scenario our R & D is pursuing. The challenge is optimizing solar and energy efficiency technology so it becomes a viable standard that can be incorporated into home building as local conditions and prices dictate.

Question: What other parts of the Department of Energy are participating in this initiative and what funding is included in each of those budgets for the initiative in fiscal year 2001?

Answer: The following table reflects all DOE funding in the fiscal year 2001 Congressional Request for the Scientific retention and recruitment initiative.

Other DOE Funding in FY2001 for the Scientific Retention and Recruitment Initiative (dollars in thousands)

Fossil Energy	600
Energy Supply	
Solar and Renewable	30
Nuclear	150
Total Energy Supply	180
Science	2,000
Weapons Activities	3,600
Defense Environmental Management	1,000
Other Defense Activities	
Nonproliferation & National Security	1,000
Fissile Materials Disposition	100
Total Other Defense Activities	1,100
Nuclear Waste Disposal Fund	100
Total Department of Energy	$ 10,650

FY99 Appropriations $3.60
FY2000 Request $5.50 million million Solar Buildings

Question: The original budget request for FY2002 would have reduced DOE research for all renewable sources, except for biomass and biofuels, by approximately 50 percent. The Administration has recently submitted a budget amendment that would restore funding for some of the renewables to FY2001. However, this amendment does not propose to restore funding for solar and photovoltaic technologies. Explain the technical and policy basis for reducing the DOE investment in this particular technology.

Answer: The Nation needs a balance of clean and reliable near-term and long-term energy options. Solar continues to be a technically viable option. The funding request for solar programs, including photovoltaics, is significant at about $43 million, and is still more than most other programs in the renewable portfolio.

Wind

Question: The United States is the most advanced country in the world and the leader in many areas of technology, but renewables is not one of them. New wind turbines that are currently being installed in the Pacific Northwest are designed and built in Denmark. Europe and Japan are the leaders in renewable energy technologies and what can this Administration do to help U.S. manufacturers regain leadership in this field.

Answer: The picture is not as bleak as suggested, and varies by renewable technology. For example, the United States is currently second in the world in terms of installed wind powered generation capacity. Based on announced industry development plans and construction starts, we project at least 1,500 MW of newly installed wind capacity additions in 2001 in the United States. One U.S. wind turbine manufacturer is supplying over 25% of this new capacity, and is among the top five wind turbine manufacturers in the world. In the case of photovoltaics, the U.S. is the world technology leader despite intense international competition. This is evidenced by the establishment of several U.S. world record solar cell efficiencies that have been achieved during the last five years.

Achieving greater renewable energy technology leadership in the United States requires sustained investment in research and development, as well as policies that help stabilize domestic markets for renewable energy. The President's National Energy Policy (NEP) report includes thirteen recommendations to increase use of renewable and alternative energy, including several that directly address both of these needs. The report specifically recommends supporting next generation technology research and development for alternative forms of energy. Through a continued focus on both fundamental and applied R&D, in collaboration with industry, we will help the United States achieve greater leadership in the development of advanced renewable energy technologies which, in turn, will lead to increased sales.

As pointed out in the NEP, an example of the opportunity for securing technology leadership in renewable energy is the pursuit of wind systems for cost-effectively harnessing lower wind speed resources, which are much more broadly available than wind resources being developed today. Because of less intense cost competitiveness of their domestic markets, foreign wind technology concerns are not emphasizing low wind speed R&D. The Department of Energy is already focusing on R&D that will provide the technical foundation for the U.S. wind industry to become the world leader in low wind speed technology. This advanced technology, which will expand the cost-competitive domestic wind resource base twenty fold, is essential for continued long term growth and significant contributions of wind power (more than 40,000MW by 2020) to the U.S. electric supply portfolio.

The National Energy Policy also endorses extension and expansion of tax credits that are critical investments for allowing a U.S. renewable energy industry to develop. For example, consistent financial incentives have been available for wind power development in Europe for a sufficient period of time to attract and support numerous wind turbine manufacturers. The on-again/off-again availability of a Production Tax Credit in the United States has been a significant impediment to establishing a robust U.S. wind industry. In response to the NEP, the Departments of Energy and Interior are also evaluating access limitations to Federal lands in order to increase renewable energy production and help to expand and stabilize domestic energy markets.

Question: Many farm-belt states are net energy importers, costing billions of dollars to these already strapped rural economies, and high energy prices are making the situation even worse. Despite the fact that several studies have documented tremendous potential for renewable energy in these states: South Dakota, for instance, is ranked as one of the highest states for wind energy potential, the region has had trouble capitalizing on these resources. Do you support federal initiatives that would lead to significant growth in the industry, especially in these states where the potential is so great?

Answer: I believe there is an appropriate role for the Department to cooperatively help the farm belt states respond to their energy issues. There is an excellent opportunity for renewable energy technologies such as wind and biomass to become an important new industry that can strengthen local and state economies throughout rural America. While each state will ultimately have the responsibility to assure that their individual policy, legislative, and regulatory framework supports renewable energy, the Federal government can and should help introduce new opportunities to the states by providing central leadership and coordination in overcoming the common barriers faced by renewable technologies. This past year, DOE co-sponsored wind and biomass energy workshops in several states throughout the Midwest and Upper Great Plains, including South Dakota, North Dakota, Nebraska, Montana, Kansas. In each instance the response was overwhelming, the information and assistance we provided was well received, and the workshop has led to a focused state effort to seriously explore wind and biomass development.

As one example of how renewable energy can help rural America, wind energy is compatible with farming, ranching and many other outdoor uses. Farmers plow right up against service roads, cattle graze up to turbine pads, and land owners love the additional revenue. In Iowa, participating farms typically have 2 to 6 turbines on them. Land owners receive about 2 percent of the gross revenue from annual power sales, or about $2,000 per turbine. At a time when the farm economy is in tough straits, wind power appears to be an ideal crop.

Likewise, the great potential of American farm belt -- the world leader in the production of food and animal feed B could also simultaneously be harnessed for production of biomass energy feedstocks. It is my understanding that the Department of Energy has made substantial progress toward this end by collaboratively working with farmers, power generating companies, and ethanol producers to examine and test concepts for using both dedicated energy crops and food crop residues to produce electricity and ethanol for transportation fuel. Supportive policies such as state tax measures supporting land use for energy crops (New York) and a special exemption by the USDA's Conservation Reserve Program (CRP) that allows farmers to periodically harvest energy crops from CRP lands (Iowa). Federal tax incentives such as the Section 45 tax credit for biomass power production have also generated interest.

While we are just commencing the development of a new, comprehensive national energy plan for the United States, I believe that the research and development of renewable energy technologies -- such as cofiring biomass with coal for power production and finding lower cost methods of ethanol production for cleaner transportation fuels -- will comprise an important part of our country's future energy mix. Development of such technologies also hold the promise of further encouraging the most efficient and productive use of our Nation's world-leading agricultural capability while enhancing state (and national) energy independence, strengthening farm economies, and improving soil, water and air quality.

Question: Wind power is the fastest growing source of energy in the world, with over 17,500 megaWatts of installed capacity. U.S. capacity is just over 2,500 megaWatts, which provides nearly 6 billion kiloWatt-hours of electricity annually or enough to power 600,000 homes. Those domestic totals are expected to nearly double in 2001. Furthermore, the cost of wind is currently 3-5 cents per kiloWatt-hour, comparable to new coal and natural gas facilities. Under your leadership will the Department of Energy continue to support initiatives to increase the percentage of electricity derived from wind?

Answer: President Bush has reaffirmed his commitment to increased production from conventional and alternative domestic energy sources. Until we've completed development of a national energy policy, I cannot comment in detail. However, as one of the most rapidly growing sources of energy in the world as well as one of the quickest to install, I would expect that wind energy would play an increasingly important role in domestic power production.

Question: Another renewable energy program showing great promise these days is the wind program. In cooperation with your National Renewable Energy Laboratory, we now have the first utility-grade wind project in Alaska at Kotzebue above the Arctic Circle. The first three wind turbines are operating, and to date successfully, I might add, nine more units are on order. In addition a cold weather technology center is planned. May I assume your Department's continued support for this project and the promise it holds for rural, northern latitudes communities around the world.

Answer: The Department and the National Renewable Energy Laboratory will continue their support of the Kotzebue wind project. This project has the potential to serve as a model for the installation of wind energy systems in other rural communities in Alaska and elsewhere that are at present totally dependent on diesel generators for the production of electricity. The Kotzebue Electric Association, the utility that serves the community of Kotzebue, believes that the experience it gains in the operation of its wind energy system may enable it to become a focal point for information on cold weather technology. Ultimately, this expertise may enable Kotzebue Electric to market its services to help establish wind energy systems in other northern latitude communities in Alaska and in foreign countries.

Question: This year you took a major step back on your support for wind energy - what's the explanation for this dramatic turnaround? We're already losing the international battle for the wind market and your budget sends a signal that we're no longer concerned about our international competition. How will reduced federal funding impact our U.S. wind industry?

Answer: We believe that the wind program should be modified while protecting our core competencies pending recommendations from Vice President Cheney's Energy Task Force. We are committed to ensuring that the U.S. wind industry continues to strengthen our domestic energy supply and the competitive position of U.S industry.

Dollars in thousands

	FY2001	**FY2002**	**$Change**	**%Change**
Wind Energy Systems	$39,553	$20,500	-$19,053	-48%

Question: If the cost of energy from wind has improved dramatically as you say in your budget request, why do you still need an R&D program?

Answer: While wind technology has improved significantly in the last 20 years, evolution of the competitive marketplace continues to pose some pricing challenges to the commercialization of wind power. Natural gas technology for example, has also improved its combustion technologies in ways not foreseen 20 years ago -- today one cubic foot of gas can do the job that took two cubic feet 20 years ago. In order to compete more broadly with the other energy sources, the cost of wind power must be reduced for the next generation of wind turbines that can use the wind resources available across much larger expanses of the country. As the electricity marketplace changes from regulated to more competitive markets lower initial cost options such as natural gas (at historic prices) are attractive to risk averse investors. Thus to take advantage of the opportunity wind energy presents to expand the domestic energy base R & D is still needed to reduce capital costs and expand its use.

Dollars in thousands

	FY2001	FY2002	$Change	%Change
Wind Energy Systems	$39,553	$20,500	-$19,053	-48%

Question: How can you be so sure that additional wind R&D has a payoff to the United States?

Answer: Wind technology costs of energy have declined from 10 cents per kWh 10 years ago, to 4 to 6 cents today in good wind regions and are expected to drop further in the next few years. The major hurdle is the need for competitive technology from several vendors for the more available low wind speed sites. The next generation of wind technology needing collaborative R&D is the 'low'-wind speed machines.

Wind technology can be improved by systems engineering and improved components. With assistance from the National Renewable Energy Laboratory (NREL) and Sandia National Laboratory (SNL), Enron Wind has reduced the cost of their Z-750 series turbine by over $100,000 per turbine. Without subsidy, the Enron 1.5 MW is expected to deliver energy at 3.3 cents per kWh. Enron's their Next Generation Turbine under development with NREL is projected to be below 3 cents in a high wind resource class region.

Dollars in thousands

	FY2001	FY2002	$Change	%Change
Wind Energy Systems	$39,553	$20,500	-$19,053	-48%

Other

Question: What are the potential benefits for the power sector of R&D investments in advanced flywheels, super-capacitors, superconducting magnetic energy storage (SMES), compressed air energy storage (CAES), and advanced battery technologies?

Answer: Each of these technologies is a distinct approach to reap the benefits of better energy storage systems. Energy storage can improve the efficiency and reliability of the electric utility system by reducing the requirements for spinning reserves to meet peak power demands, making better use of efficient baseload generation, and allowing greater use of intermittent renewable energy technologies. Efficient, reliable storage devices allow certain forms of distributed generation to succeed in broader applications by utilizing stored energy during periods of peak demand. These advanced technologies are in various states of development and carry a high level of investment risk that necessitates federal involvement in their development.

Dollars in thousands

	FY2001	FY2002	$Change	%Change
Electric Energy Systems Storage	$5,987	$5,987	$0	0%

Question: What is the status of state efforts to implement electricity restructuring?

Answer: As of April 2001, 24 states have enacted electricity restructuring legislation and 18 other states have ongoing investigations, either by the public utility commission or by the State legislatures.

Question: What is superconductivity and why is it important?

Answer: Superconductivity is the ability of certain materials to conduct electrical current with no resistance and extremely low losses. The technology can be applied to electric power devices such as motors and generators, and to electricity transmission in power lines. The superconducting equipment now being developed promises to meet the needs of a higher capacity, more efficient, more reliable electricity system.

A superconducting power system could meet the growing demand for electricity with fewer power plants and transmission lines than would otherwise be needed. For example, transmission line losses that account for a large amount of wasted energy in today's infrastructure can be drastically reduced through the development of superconducting equipment, changing electricity from a regional to a national commodity.

Superconductivity will also assist in providing large amounts of electricity to high-density urban areas by carrying more power through each wire. Superconductivity is a priority of the Department of Energy and an important part of providing a new, successful electricity infrastructure that should reach marketability within the next 10 years.

Question: There was an increase in the FY01 appropriation to accelerate development on the "second generation" of HTS (high temperature superconductivity) wires. What has resulted?

Answer: A total of $6 million from the FY01 appropriation (the appropriated amount increased $5M over FY 00) accelerated development in two important ways:

1. Additional effort was initiated in three competitively awarded contracts for industrial scale-up of breakthroughs at Los Alamos and Oak Ridge, and,

2. New laboratory equipment was purchased and new staff added at Los Alamos and Oak Ridge National Laboratories for increased collaborative research with private companies. A laboratory at the new Los Alamos Research Park will be dedicated this summer for laboratory/industry joint work, and laboratories at Oak Ridge were consolidated in April to bring together researchers that were previously scattered.

Joint research at the national laboratories is essential for industrial development of these exciting technologies and the new equipment gives the laboratories the facilities needed to do this. Successful collaboration helps to ensure continued U.S. leadership in this area.

Dollars in thousands

	FY2001	**FY2002**	**$Change**	**%Change**
HighTemperature	$36,819	$19,000		
Superconductivity R&D		$17,819 amendment		
		$36,819	$0	0%

Question: What is the Transmission Reliability program doing to support the western energy situation?

Answer: The program is developing real time monitoring tools to support the Independent System Operators managing parts of the national grid. The program is also evaluating regulations to determine ways to promote competitive markets, to deter market gaming (monopoly by one utility), and to eliminate market barriers by developing national standards for interconnectivity.

Question: Explain the purpose, process, and funding for the Department's initiative to create a National Alliance of Clean Energy Incubators. Explain the competitive process used to select the particular non-federal partners in this initiative.

Answer: The National Alliance of Clean Energy Incubators is a National Renewable Energy Laboratory (NREL) effort to assist small energy companies entry into the market arena. While many small clean energy companies are capable technology developers, they lack the business acumen to successfully enter the market place. Incubators accelerate the growth and success of companies by providing mentoring, business services and expertise, and access to capital.

Working through State Energy Offices, NREL spent a year to identify and align with experienced, existing incubators, who had an excellent network of resources and business expertise. NREL targeted states with a good support base for incubators and clean energy. It was equally important to find incubators with a strong desire to work in the clean energy area. There are currently eight partners in this seven state effort. No NREL funding goes to any of the incubators.

Question: What is the impact of the FY2002 budget request for the Office of National Renewable Energy Laboratory?

Answer: Although the funding dedicated to NREL is proposed to increase slightly over FY 2001, the overall budget for Renewable Energy Resources is proposed to decline by 36 percent, from $373 million in FY 2001 to only $237 million in FY 2002.

The National Renewable Energy Laboratory (NREL) is the Department of Energy's premier laboratory for renewable energy technology development. NREL houses the National Center for Photovoltaics as well as the National Wind Technology Center. The proposed funding reductions for Renewable Energy Resources may have a negative impact on staffing at NREL, particularly in the technology areas of Solar and Wind technologies. The exact magnitude of this potential impact on R&D is being determined.

NREL is also a focal point for research and development areas that are being emphasized in the FY 2002 budget request. NREL's role in the development of Biomass technologies is of high importance as its role in Distributed Energy Resources and Hydrogen R&D. The Department is also looking at taking actions that could help mitigate the magnitude of the potential negative impact. In a reduced budget scenario the Solar and Wind programs will be studied to see if any consolidation of activities at NREL is feasible rather than implementing the program across Departmental locations. The amount of subcontracting by NREL and other laboratories will also be reviewed to determine additional in-house research and development activity that could be undertaken at NREL. These Departmental actions coupled with NREL's growing role in technology development could mitigate some of the negative potential for staffing reductions at NREL.

Question: What is your office doing to address this country's aging electricity distribution infrastructure?

Answer: The transmission and distribution systems in the United States are regulated by the Federal and State governments, respectively. The U.S. transmission system was not designed to support the sale of energy and ancillary services that are becoming available through competitive markets, which is causing heavy power flows and stress on the grid. This subsequently causes congestion points on the grid that, to date, are relieved by redispatching generation, and overriding energy purchase decisions under competitive markets.

The Department has initiated a National Transmission Grid Study to examine the benefits of a grid that supports full competition, and identifies bottlenecks and measures to remove them. The study, to be published by December 31, 2001, will contain recommended actions for the Department and electricity industry stakeholders to move toward a grid for competition. Current programs within the Department's Office of Power Technologies are aimed at upgrading the capacity of existing transmission corridors without building new lines. These are listed in the following table:

Technology	**OPT Program**
Real Time Monitoring and Control Systems	Transmission Reliability
Advanced Composite Overhead Conductors	
Demand Responsive Load Control	
Superconducting Technology	
Transmission and Distribution Cables	High Temperature Superconducting
Transformers	
Flywheel Storage Systems	
System Integration	Energy Storage Systems
Subsystem Development	
Strategic Research and Analysis	
Strategic Location of New Generation Units	Distributed Energy Resources

These programs will allow the industry to upgrade the transmission system by integrating alternative generation, energy storage, and demand control options, along with new transmission technologies into a energy services delivery infrastructure that facilitates full competition and provides service choices down to the individual customer.

Distribution systems are under State regulation where public service commissions can provide rate relief and regulatory pressure to ensure adequate maintenance and operation. The Department is drafting a report that responds to a recommendation in the Power Outage Study Team report to support reporting and sharing of utility "best practices" for maintaining and operating distribution systems.

The Department intends to work with the electric power industry to facilitate the collection and sharing of information on "best practices", and promote the use of uniform definitions and measurements for reliability-related events. Other report recommendations DOE is implementing are the removal of barriers to the use of distributed generation and storage, development of ways to allow customer participation in competitive electricity markets, and public interest reliability-related research and development consistent with the needs of a restructuring electricity industry.

Question: What does reliability measure?

Answer: Reliability is a term that measures the length of electricity outage periods. ‘Three nines reliability’ or 99.9% reliability, is equivalent to about 25 hours of outages per year. ‘Six nines reliability’ refers to approximately 31 seconds of outages per year. Some customers however may have longer down times due to equipment jams and cleanup.

Dollars in thousands

	FY2001	**FY2002**	**$Change**	**%Change**
Transmission Reliability	$8,940	$8,940	$0	0%

Question: The FY01 Senate Report under "Electric Energy Systems and Storage" urged the DOE to "begin a research program to develop solutions for grid reliability issues through the use of advanced computer simulation capabilities available within the national laboratories. What has the Department done to respond to this language?

Answer: The Pacific Northwest National Laboratory (PNNL) is leading a project to use real time data to validate existing models in the Western electric power system, and establish specifications and standards for data sharing and communications for real time control systems. PNNL and the Oak Ridge National Laboratory are investigating the integration of on-line and off-line security analysis software tools to manage security assessment and congestion management in a grid that is becoming increasingly complex. The Department also supported discussions with Los Alamos National Laboratory concerning their capabilities in computer simulation and power system analysis for possible participation in the program.

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